Remote Sensing Essentials
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Module No # 06
Lecture No # 27
Spatial Filtering, Band Rationing and
Principal Component Analysis Techniques

Hello everyone and welcome to the new discussion of this remote sensing essential course and today we are going to discuss 3 things one is spatial filtering earlier few times I have mentioned this thing and also band rationing and I will be showing through software demonstration later on. And third technique is principal component analysis techniques. So band rationing and principal component analysis techniques are perform multi spectral data whereas this spatial filtering technique can be performed in single band or on a color composite also.

But band rationing of course you require minimum 2 number of bands and for principal component analysis you require at least 4 bands to perform this one.

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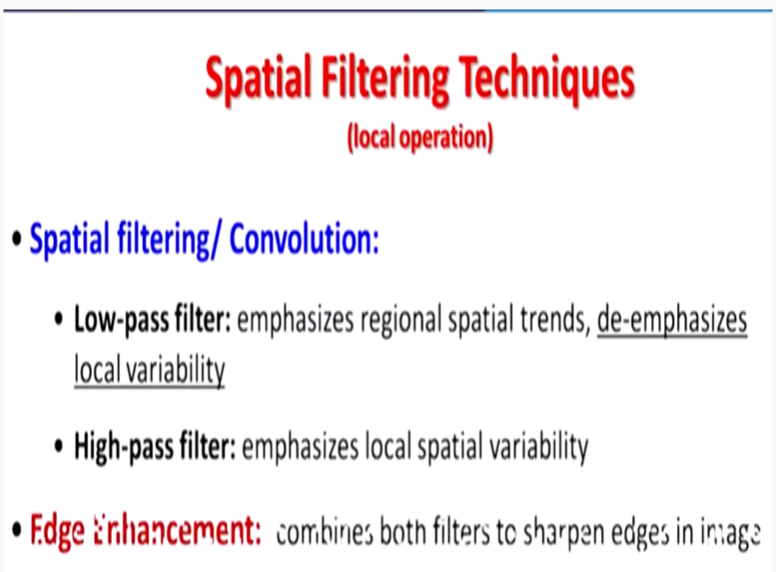

So we will start first with the spatial filtering technique and these are also called a local operations basically the main purpose of this thing after the enhancement if you want to see more sharpness in the image or more smoothening in the image then we go for this spatial filtering techniques. So basically also it is called convolution techniques or convolution filtering technique.

2 main categories of filters are spatial filters are known in digital image processing of remote processing of remote sensing data. There might be some other filters and the concept of these filtering techniques have come through the you know ahh electrical or electronic engineering to filter the different ways or moistures here it is spatial filters other than a linear or a slit filter. So we are talking about this spatial filter not the filter which is generally used for a wave noise clearance and other things.

2 main types one is the low pass filters basically which emphasize the regional spatial trends make your image more smoothen and deemphasizes local variability. So whenever you require that you want to see the regional things rather than local things then low pass filter is employed and when we want you know local things should be emphasized then we go for high pass filter. So these are the 2 major things are there of in different types of filters in high pass category and one we can put as edge enhancement so which combines basically both filters but a mainly focus is on the edges of your main features.

Suppose there is road you want to emphasize that road on an image or a linear feature on a satellite image may be geological features or some other feature then for that purpose we use edge announcement. So locally the features which you want to emphasize or enhanced and regional things are not announced there. So as I was just mentioning that if I take this single wave on the top figure A.

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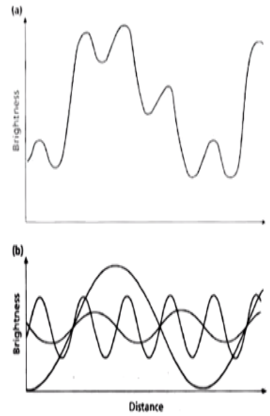

Variations in digital number (DN) along a line on an image (a) can be expressed as a range of sine waves (b) with different amplitudes and frequencies. Their cumulative effect is the same as the real spatial frequency distribution of the image.

Lillesand and Kiefer, 1987

It is the combination of 3 waved of different amplitudes and frequency are there so if we apply filtering on top figure of different frequencies this is what we will get. So the bottom one is showing basically the combination of 3 waves in a total one wave form. So thus the other you know when you are going for a slit kind or linear filter but the filter which we are talking is basically the spatial filter.

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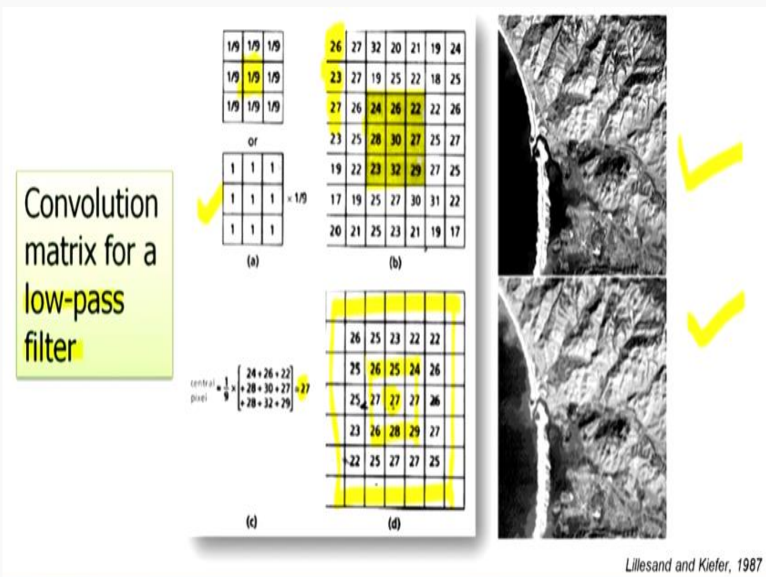

How these filters looks and how this is performed on an image this we will be discussing now basically these are convolution matrix and the example which I have taken now is the low pass filter. So what we will what here we see that is a example of low pass convolution matrix filter. A filter is basically 2 dimensional matrix that might be 3 / 3 pixels or maybe 5/5 pixels or 7 or it has to be odd number the reason is because for the center pixel which it will calculate the value from tha image which is subjected for filtering in this case the low pass filtering.

So if I take more simple example of like the second one which is having an all cells of filter spatial filter we are having one value and all this cell values suppose this says put here then corresponding cell values will multiply with whatever the cell value in the filter. Here in our case all cell values are 1 so 24 multiply by 1, 26 multiply by 1 and likewise and then they are total divided by 9.

So what will happen it will create an average value using the surrounding pixels to the center pixel which is in out this example it is value having 30. So by which it will smoothen the image and as result you can see in the bottom so this is the input image which you are seeing here which has been subjected to low pass filtering and more smoothening has occurred in this image after this filtering which is given there.

So the only problem in spatial filtering is what happen on the edges because if I want to calculate new pixel value through filtering for this corner pixel or the pixel which are on the edges then I cannot put my this rowing matrix over 26 because then I reach to the outside of an image. So output image will have a 1 row 1 column like this on all boundary 1 pixel thickness boundary without any values.

So it will not calculate and that will be stored in the image as well so that is the only limitation which we are having for either low pass filtering or high pass filtering that the edges 1 pixel thickness edge if it is a 3 /3 pixel spatial filter. If this filter is 5 / 5 then 2 pixel thickness rows at the bottom and top in same in the left and right will not be considered or spatial filtering. And if I go for 7 / 7 then it will be 3 so likewise only in the edges we are having problem.

So this kind of trade off the purpose here was to smoothen the image so that I can see the more regional features rather than I get distracted because of local variations or local features. For that purpose the convolution matrix of low pass filter can be applied the example here also given for the center pixel like this and all these pixels have been considered while calculating the values and this is how the low pass filter will work.

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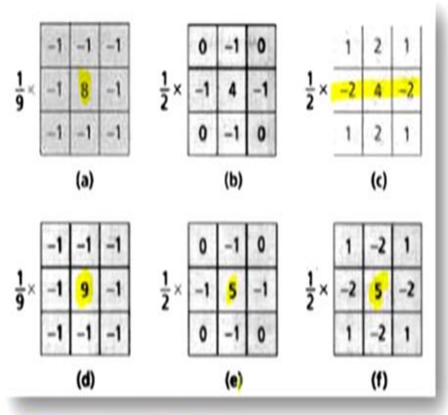

Convolution matrices for edge detection or **high-pass** filtering can be achieved by subtracting the results of a lowpass convolution from the original image (a), or by devising matrices based on more complex algorithms (b and c). Edge enhancement matrices result from adding the edge detection of the original image (d, e and f).

There can be many other filters which are the examples of high pass filters here the purpose here to emphasize the local features and deemphasize the regional features therefore in all of these examples which are shown here A, B, C, D up to F all are some values some cell values of this filter are in negative because the main purpose remember is that we want to emphasize the local features one. So on the edges of these filters though we have taken the simplest example that is 3 /3 filters none the less some values are always in negative one.

And the center values like here 5, 5, 9 these are higher values so what would happen when these filter will go on an image cell pixel for calculation new pixel value pixel after pixel throughout that image then what will happen because of this high value in the center that will be used in to emphasize the local features and at the same time it will deemphasize the regional features. Whereas in case of low pass filter and no spatial treatment for the center pixel and therefore like not giving 8 value or 6 value here every value is the same because the purpose here is to deemphasize the local features which is just opposite to high pass filter and emphasize the regional features.

So just whenever you see a this kind of filter matrix and this convolution matrix whenever you see if you see any negative value 1 and the center value is high you can immediately guess that it is a high pass filter. If we are going for edge deduction then we must know that for which direction we want to emphasize the features that is why there are on some cases like if I take this examples only 2 values are having minus rest are having positive values.

So what you basically the purpose here is by devising metrics based on the more complex algorithms which is example of B and C. So edge enhancement metrics results from adding the edge deduction of the original image for example d, e, n and f. So of we know these things then we can emphasize that I want to enhance the only edges not all features local features through high pass filter so these are the tool.

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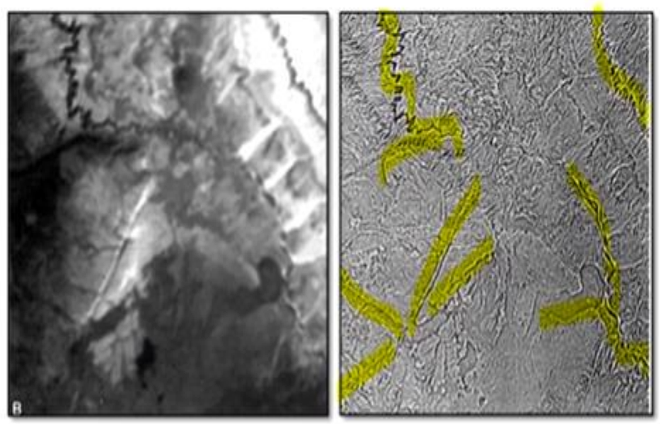

High pass filter image in which the convolution matrix is 11 x 11 pixels

Now let us see the example here this is the example of high pass filter in which the convolution matrix of 11 / 11 pixel not 3/ 3 not 5/ 5 not 7/7 and 11 by larger the this convolution matrix would be larger the size of the filter would be it will encompass large pixel values to calculate the pixel value for the center pixel and therefore since it is the high pass filter. So what did has done it has deemphasize all regional features because it is a 2 relatively very large size filter 11/ 11.

And therefore it deemphasize the regional features and highly emphasize the local features and that is what you are seeing this edges of all these features which we are more or less dull in original image have been emphasize like anything that you can see very the all linear features or edges of all features have come up very clearly. So that is the advantage of high pass filter however larger the convolution matrix for special filtering is whether it is a low pass or high pass more the time it would take for processing.

So if you are having a very large image then the in the practice what you should do you should take a subset of the image and try to perform you know filtering using same concept you may be using 5 /5 or 7/7 and once you are sure that now I want this filtering for entire image then run for because if this is a more or less objective or require some iteration till you find the output is suitable for your project till then you will keep trying different options.

So the best thing is create a subset of the image try all kinds of filtering and once you are satisfied then take the entire image and run that filter which is most suitable to you and in that way you would save lot of time. Otherwise for large image having 11/11 convolution matrix will take lot of time for processing.

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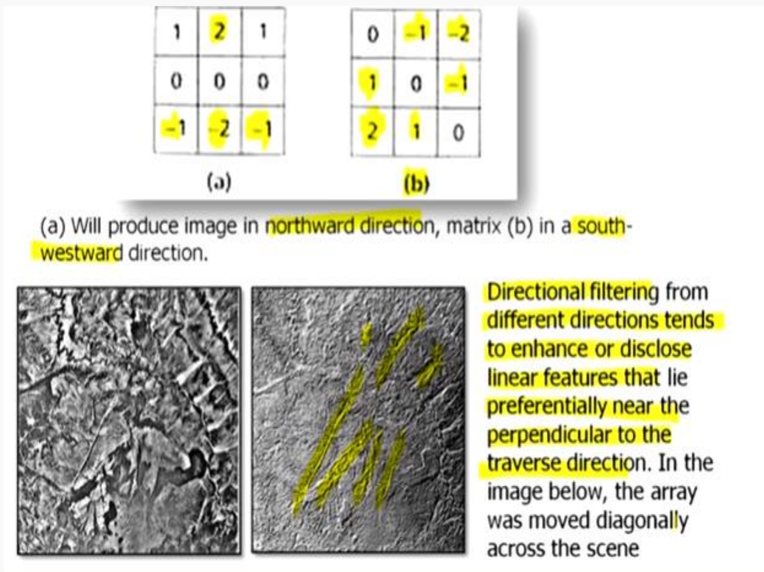

Similarly directional filtering is also possible like edge enhancement wherever edges through high pass filtering it will be emphasized. But I want in a particular if I know that there are features say they are running in east west direction or in north south direction. So I want to emphasize those features linear features and for that I will be using directional filtering 2 examples are here 1aa is the example for the north ward direction that means the features are in the north you know north south direction.

Now if you see carefully this convolution matrix of 3/3 you see that here I am adding more values to my center pixel in north ward direction and whereas in the southward direction I am having negative values. And same in the southwest direction and same in the southeast direction though value is -1 -1 in both these corners but the southern side I am having 2 so that is why it will produce an image which will have more emphasize in the northward direction.

And whereas if I want a southward direction this is the south west direction in case of b then I will put the values negative here in opposite corners and then these values that means the features which are having orientation north south they will be emphasized northeast southwest. So here the north sorry southwest direction features will be emphasized. So I even looking a filter convolution matrix you can understand that what effect it is going to be on image once this is used for filtering.

So likewise and not only low pass filter not only high pass filter you can use the edge enhancement for that you sometimes go for very large convolution matrix like in previous example 11/11 or also you can use the directional filtering. Let us see now one example here that this is the input image on the left side and on the right side you are having the filtered image directional filtering.

So directional filtering has been done and what you are seeing that the features which are in the northeast southwest directions like these one they have been emphasized very significantly and whereas it is not very easy for anyone to pick up those features very easily in the unprocessed or raw image. So these what from the different directions stands to enhance or disclose linear features because our aim is to find some linear features present in the image in many sciences related work in petroleum explosion ground water explosion mineral explosion these linear features plays very important role or maybe in many civil engineering projects also.

So therefore these are required so you have to emphasize in one direction and in convolution matrix that has to be in the opposite direction. So preferentially near the perpendicular to that transverse direction and what you are seeing that this filtering has been moved throughout the image except 1 pixel thickness on all sides.

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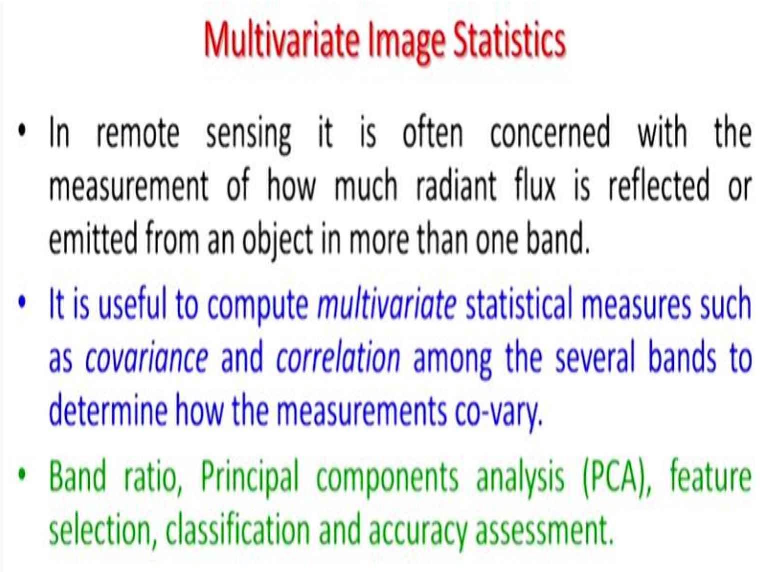

Now so far what we have been seeing the examples and discussing on single band however you can also do the spatial filtering on multispectral images or colored images or color composite not a problem at all. But these are now also consider special filtering under uni variate image statistics or image analysis. Now we will be discussing multivariate image analysis or image statistics so 2 things band rationing and principal components.

So as you know that in remote sensing we are concern with the measurement of how much radiant is reflected or emitted from an object on more than 1 band and because we are involving now more than 1 band. So in it is useful to compute multivariate statistics which is measures as a covariance or correlation among several bands. Because you know that if you see the band after band in a continuous passion you may find that they are sometimes they are highly correlated.

And we want to use those bands in our may be color composites or in some analysis multispectral analysis where end-user bands are less correlated. And for that purpose we may perform multivariate image statistics. So band ratio is one of the technique principle component or in short we also called as PCA may be feature selections classifications and accuracy assessment all these will come under this multivariate statistics.

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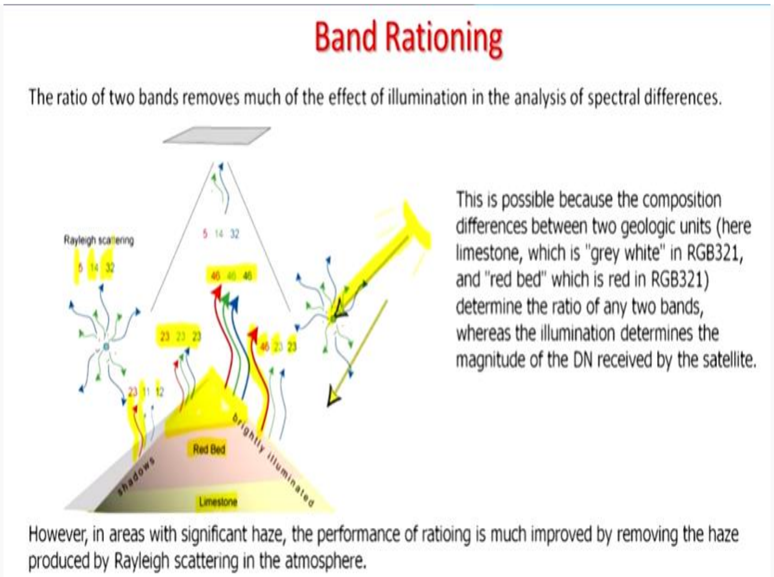

First we will go for a band rationing involved 2 bands basically and as if you see in the figure and some values are also given there that the solar radiation is coming here and whatever is from different surfaces one surface is example is shown limestone another example is red bed and then you may be having soil on one side this brighter because sun is on this right side whereas on the left side it is in the shadow.

So the values which you are seeing are different values which you are coming after the reflection from different surfaces which you are seeing here. So it is possible that these values will of coarse will give different reflection but if there are 3 bands scenarios are there red, green and blue. If I take this example that from this surface this is marked yellow here all are giving almost same reflection but when we go to the red band that in the red band or red channel is having value 46.

Whereas other green and blue in that band their reflection is just 23 if I go in the shadow side then the values here instead of 46 all values are 23 but red band is again having maximum that is 23 and rest are having 11 and 12 because it is in the shadow side. Now if there is a scattering effect and other things these values will further be reduced and we might be getting values only up to this much 5, 14, 32. So if we perform band rationing we can exploit these differences which is occurring in different bands and can create new outputs and very useful images to receive.

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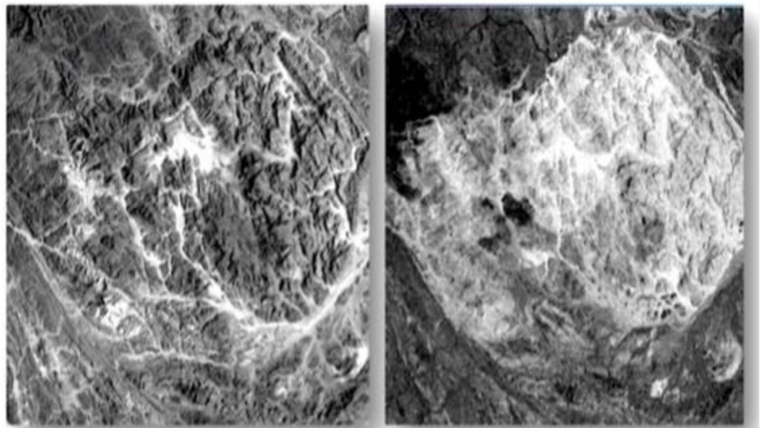

band 1 (blue radiation) shows strong topography because of differences in illumination (TM image, part of Egypt)

The ratio band3/band2 removes much of the effect of illumination and yield differences in rock type.

Let us see the example here on the left side you know band one which is the blue radiation as we which shows that their hardly I can differentiate between different rock units which are present here or land covers which are there. But when I create a band ratio between band 3 and band 2 this is example from land sat TM. Then I clearly get clear unit which comes out in the band ratio image which is not possible in band 1 because of the topography is not allowing us to see the much different into (()) (22:06) units.

Whereas on the right hand image when I create a band a ratio of band 3 and 2 that removes the effect of topography illumination effects or differential illumination and will yield the differences in rock type and this is what the example is. Though output is going to be in black and white 2 grey images of band 3 and band 2 in this example I have been taken an output is in grey scale. Band 1 does not allow us to differentiate between 2 major (()) (22:42) units so this is one of the best example of it.

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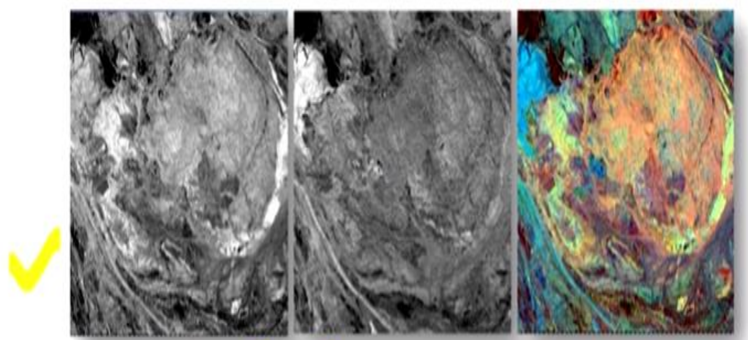

Now if I am having too many bands with us not just 4 maybe 7 maybe 10 or 20 in case of hyper spectral also. Then I can create many band ratios of different combinations and then can create a color composite of band ratio's like here this is example that these 2 other ratio's this is 5 band because this is land set 7. So we are having land set TM sensor or TM plus sensor. So we are having 7 band so the 5/2 ratio is this one first one the extreme left then this center one is the band 7/4 ratio.

And then I can create one more ratio has been created which is 3/2 as shown earlier 3 /2 so all these 3 ratios have been taken any band ratios composite has been created giving this 2RGB so 3/2 band ratio image has been assigned red color 5/2 have been assigned green color and 7/4 has been assigned by blue color. And if we do it then see that not only now 2 rock units but different rock units are coming out very clearly.

Otherwise you see if you compare with this first image band 1 you just one can interpret that everything is almost same as per the rocks are there or land cover is there. But when we see here now we are saying all there are many at least 5, 6 rock units are clearly visible in band rationing. So that is the advantage and so we have to understand one while creating these combination of band ratios that how different rocks, different vegetation or different land units would be responding through these spectral cards in different bands.

So bands 7 for example is good for showing hydroxyls common in hydrothermally altered rock this is more specific to sciences geology. But in other cases also once we understand the spectral response curves for different bands then of different features then I can create those band combinations band ratios and then create it finally it a composite image which is a band ratio composite image.

So in normal false color composite image will never give you such results a single 2 bands ratio will always create a black and white image. Here using 3 band ratios and giving RGB scheme additive color scheme 1 can create a beautiful outputs to discriminate different objects, different features, different rocks, different minerals very clear very convincingly. So that is the advantage of recall when we have been discussing this color space and false color composite and other things.

Now those concept which we have discussed are being used directly here so that is why those things where also important. Now one more band ratio technique but little not simple like 5/2 or 4/7 it is not little more calculation is there and that is very standard index there are many indices related to the vegetation or snow cover and other surface identification surface feature identification but the one which I am going to discuss in normalized difference vegetation index. What is happening in this index what we are doing we are infrared channel minus red channel.

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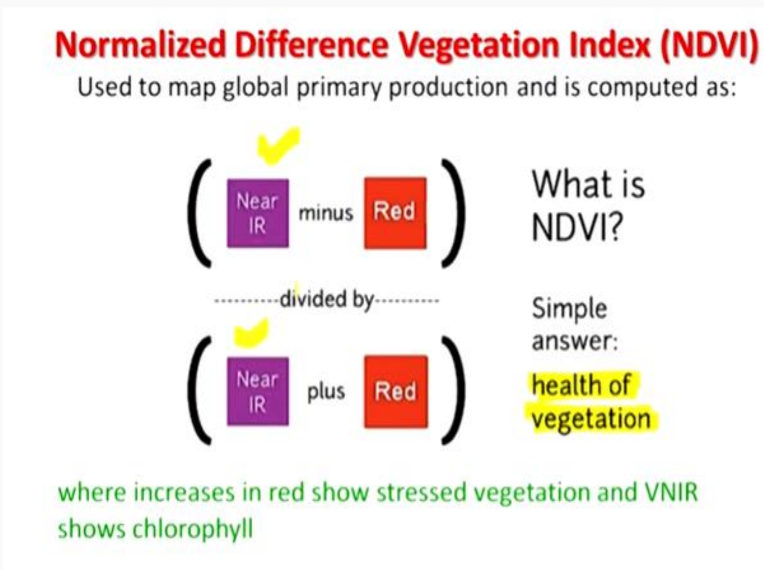

So blue green red then infrared in this sequence we get the band so first I am putting infrared channel knowing that infrared channel the vegetation will have a healthy vegetation will have the higher reflectance. So using that channel minus the red channel these will be positive quantities definitely divided by infrared plus red so again this would be a larger number than the top one.

So what would happen so that you would create an index and this can be used of coarse there will be multiplication factor and so that we rescale the values between 0 to 255 if 8 bit scenario so we multiply by 255 also. And finally we get the output which is NDVI index or NDVI image which will be showing the health of the vegetation because we have used infrared channel 2 times differently.

So where increases in the red source because there is a blue and thus if the vegetation is not healthy then the reflection you know this responses the spectral response curves of vegetation's will shift towards the red rather than remaining maximum in the infrared. So if red is increases that will show that vegetation is having stress not very good chlorophyll content and so VNIR near very near to infrared will be showing higher values.

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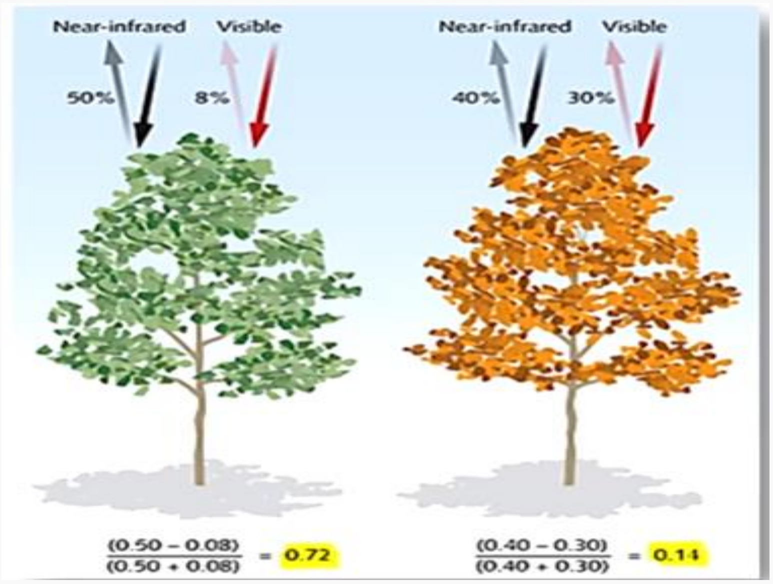

So by using this index we can assess even the quality or health of vegetation for example here 2 examples are here one is the on the left side you are having healthy vegetation in the right side you are having vegetation under stress or may be in case of deciduous trees these are trees or leafs are about to fall if this is the scenario and if we create a vegetation index what would happen. In infrared channel 50% this is schematic so 50% reflection is going back to the sensor in the infrared channel in case of healthy vegetation and whereas in visible that is the red part of visible channel it is only 8% which is going.

If you compare this with the vegetation under stress or dying up vegetation only 40% in infrared is going whereas in the visible red it is going 30%. So these values have been calculated in the bottom as NDVI so 0.5 – 0.08 and the percentage have been taken here so you 0.72 here. If we rescale in 255 we multiply that value and we get a pixel value as well. But for time being let us take 0.72 in case of healthy vegetation of this ratio basically this is also ratio.

And in case of a vegetation going under stress is having just 0.14 so you can understand where easily that a vegetation which is healthy having high chlorophyll content will have a high NDVI value and whereas the vegetation which is under stress for drying will have a very less relatively very less as in this example chlorophyll content and of coarse less NDVI value so that is the advantage.

So simple instead of simple band ratio if we employ the NDVI and normalize difference because normalize we normalize by multiplying by some factor or in 8 bit scenario may be 255 and so when we normalize it we get index and that tells us the health of vegetation.

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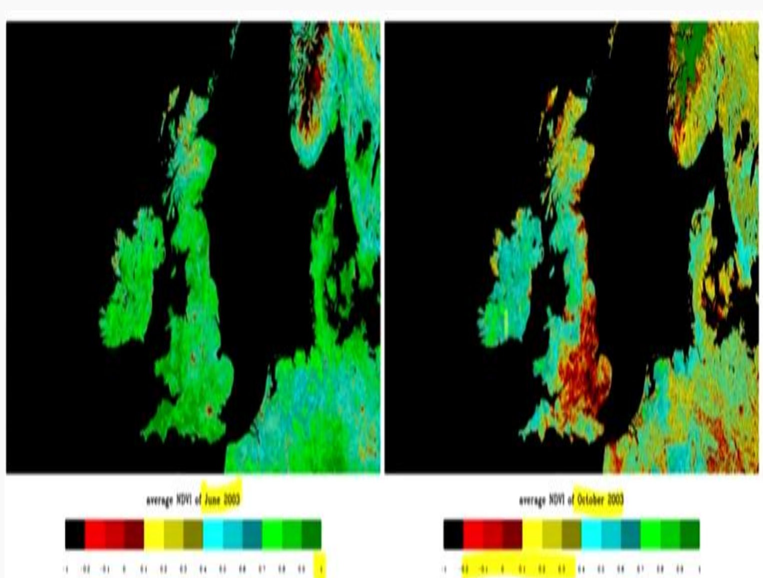

If we see in form of images this is the scenario this is the first image on the left side is June 2003 of some parts of Europe and it is completely covering united kingdom and Ireland northern Ireland too. And see the in that part of the world the in month of June the NDVI values are very high whereas in the month of October when winter is approaching in that part of the world the NDVI values are going very less as you can see because the green color the NDVI 1 means the highest NDVI here.

So early there are few places where you are getting green otherwise rest are going in very less value so these values keep changing season to season and they tells us and if not seen but if in a forest cover if some areas as showing less NDVI value there might be because of vegetation are under stress maybe because of some you know may be some elements some attack by some bacteria or whatever and that may destroy the vegetation or may be lack of water.

Sometimes in a hilly terrain if a slope is moving very slowly then vegetation also gets dry and that can also be picked up through this analysis NDVI analysis and we can demark it the area also after the field verification. Now the last part here is the principle component analysis which is very interesting and very useful also.

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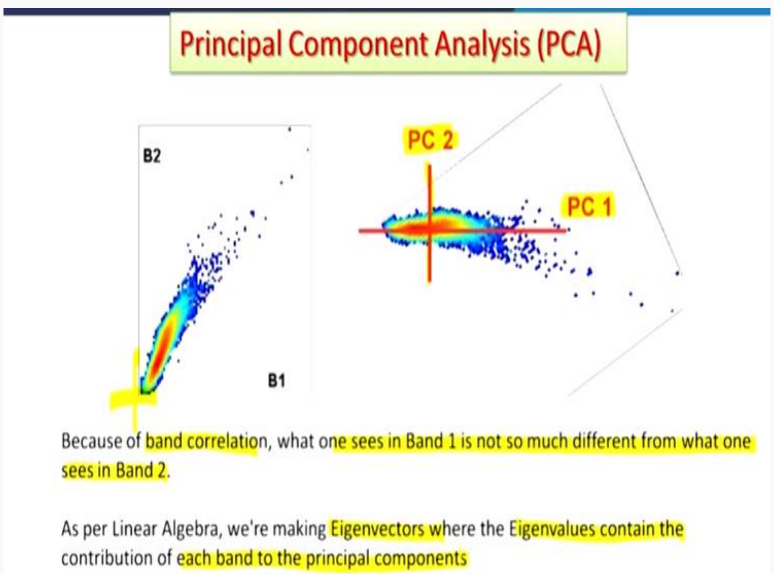

The scenario which the figures which you are seeing basically is showing example from 2 bands only and the left one is nothing but a scatter plot. So what is band 1 versus band 2 and see they are highly correlated band nonetheless here the origin of this scatter plot is here in the bottom left corner. Now in order to calculate principle component analysis first I am going to explain through graphics then the origin is basically shifted instead of in the bottom left corner it is shifted to the center of this cluster of correlated pixels between 2 different bands like here it is shown.

And the one where maximum correlation is there that is assign principle component one maximum variations sorry maximum variations which are there are assign principle component one and the one which is having relatively less variations compared to principle one perpendicular to PC1 is assign PC2. Now if I am having a 3D in 3 dimensional scatterplot then I can have one more principle component.

And but that is based on the graphics but think from you know if I am having 7 bands and I want to calculate principle component analysis through programming or through mathematics is possible but in graphics only 3 dimensions can be shown nonetheless so what because of band correlations as I have mentioned one see that the band 1 is not so much different from what band to sees and this is what the example is. So as per linear algebra we are making Eigen vectors where Eigen values contains the contribution of each band to the principle component so this is how the calculation is done.

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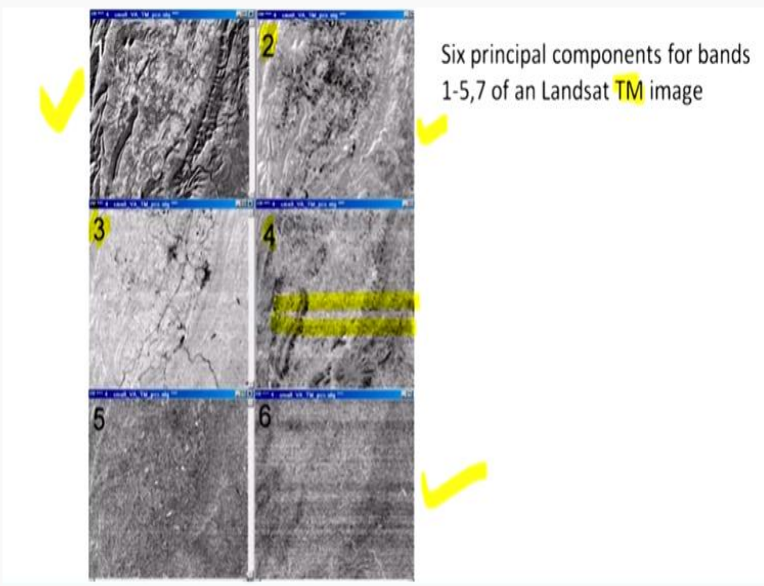

Now there are 7 bands scenario is taken in case of land sat TM and you are what you are seeing 6 components. Now see the this one having the maximum variations present among pixel values will go in principle component 1 because of high correlation among banks also. So through principle components analysis the PC1 will always carry the maximum variations. So PC1 here the top left is showing the maximum variations.

And principle components 6 generally will carry the noises so one can also use this technique to remove noises from these bands like this. Now you are having a principle component 1 which is having the maximum variation present among pixels are stored in PC1 then next is the PC2 which is here on the top right and then PC3. Like in NDVI we created a color composite using 3 bands ratios combination similarly here also this possible to create color composite using principle 1 PC1, PC2 and PC3. And in 4 as you can see are also variations but the noise or stripping effects is visible here fifth and sixth is having maximum noise.

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	Band1	Band2	Band3	Band4	Band5	Band6
Null Cells	5504	5504	5504	5504	5504	5808
Non-Null Cells	1557632	1557632	1557632	1557632	1557632	1557328
Area In Hectares	155.758	155.758	155.758	155.758	155.758	155.728
Area In Acres	384.887	384.887	384.887	384.887	384.887	384.812
Minimum	42.000	11.000	9.000	4.000	1.000	1.000
Maximum	166.000	109.000	138.000	158.000	243.000	220.000
Mean	55.962	20.497	23.222	41.811	55.429	21.343
Median	55.563	19.805	22.605	39.492	54.883	20.676
Std. Dev.	4.434	3.498	5.704	16.641	23.175	9.496
Std. Dev. (n-1)	4.434	3.498	5.704	16.641	23.175	9.496
Corr. Eigenval.	5.127	0.418	0.299	0.092	0.050	0.014
Cov. Eigenval.	864.875	85.994	11.942	2.711	2.287	0.802

Correlation Matrix	Band1	Band2	Band3	Band4	Band5	Band6
Band1	1.000	0.901	0.852	0.710	0.781	0.789
Band2	0.901	1.000	0.884	0.841	0.848	0.818
Band3	0.852	0.884	1.000	0.684	0.900	0.915
Band4	0.710	0.841	0.684	1.000	0.795	0.673
Band5	0.781	0.848	0.900	0.795	1.000	0.965
Band6	0.789	0.818	0.915	0.673	0.965	1.000
Determinant	0.000					

Corr. Eigenvectors	PC1	PC2	PC3	PC4	PC5	PC6
Band1	0.401	-0.044	0.695	-0.551	-0.218	0.054
Band2	0.421	-0.245	0.283	0.412	0.709	0.102
Band3	0.418	0.339	0.118	0.635	-0.539	-0.054
Band4	0.373	-0.764	-0.361	-0.035	-0.285	-0.255
Band5	0.422	0.182	-0.456	-0.216	0.014	0.731
Band6	0.412	0.455	-0.292	-0.276	0.278	-0.620

This is how the you know you will get the correlation matrix and of coarse Eigen correlation vectors also if you will get or so band 1, band 2, band 3, 4, 5, 6 bands have been used here. And again band PC1, PC2, PC3 and likewise and all these statistical analysis will be performed and you can achieve you can create a color composite of principle 1 PC1, PC2, PC3 giving a RGB scheme you will end up with the beautiful image and beautiful.

In the sense that it will give you more better interpretation more discrimination among objects because 6 bands color combination cannot be possible by principle component analysis not only you are removing the errors from the data but you are gathering all variation which are present in

7 or 6 bands into just 3 components and then creating a color composite. Now little variation in principle component and that more you know correlation more variations can be created by employing a technique which is called de-correlation stretch which is which can be done only after the principle component analysis.

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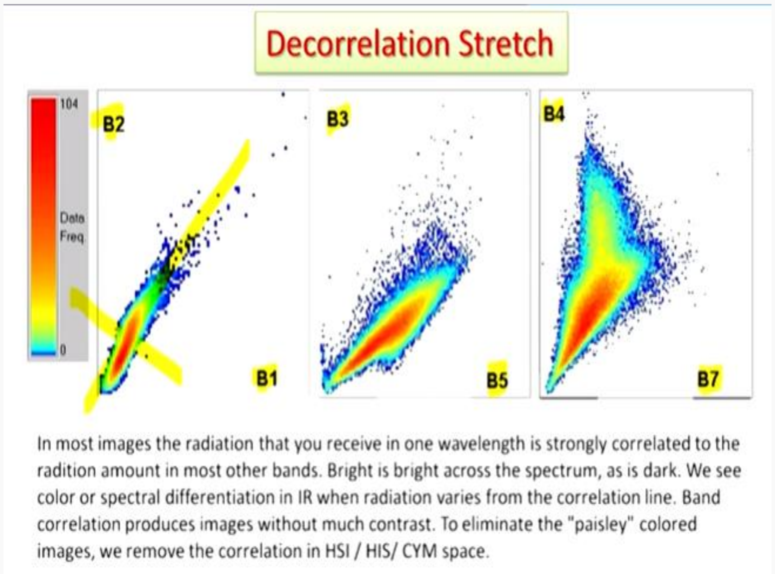

Here is the example the same example band 1 and band 2 highly correlated bands are there and in case of band 3 band 5 less correlation are there when we go for band 7 and band 4 land sat TM we see that less correlation exists. So what in de-correlation what is done basically I will explain here that these the stretches are made in both the components here no stretches are made in these output images linear stretches.

And we can linearly stretch these components and can do the de-correlation stretch that is why we are de-correlating these are the correlated bands and if I create principle component 1 that would be in this direction of coarse an origin would be here in the center of this cluster so I will linearly stretch them. And if I linearly stretch them that means I am de-correlating them and I am by this I am doing more generating more variations among bands.

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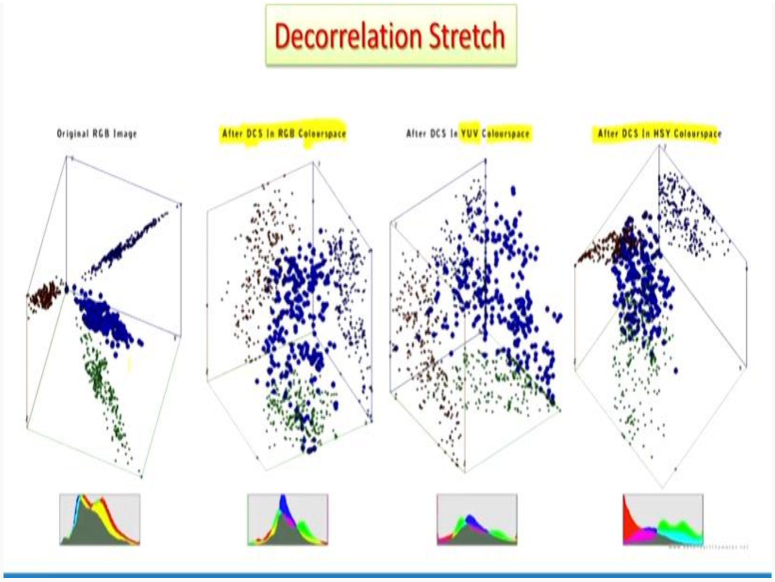

In 3 dimensional there are you know all these planes and in the center all these bands are shown and this they are respectively are very highly correlated after DCS de-correlation stretch in RGB color space this is what you see. And after DC this is in yellow and violet and other color space in different combinations you see this one and then you can have after DCS, HSY that also IHS that is intensity Hue and saturation.

Here intensity saturation in yellow color but the main important point is here that this the original plot may look like this but when you do the de-correlation stretch it would look like this that means you have de-correlated each correlation among bands and will have a maximum variation.

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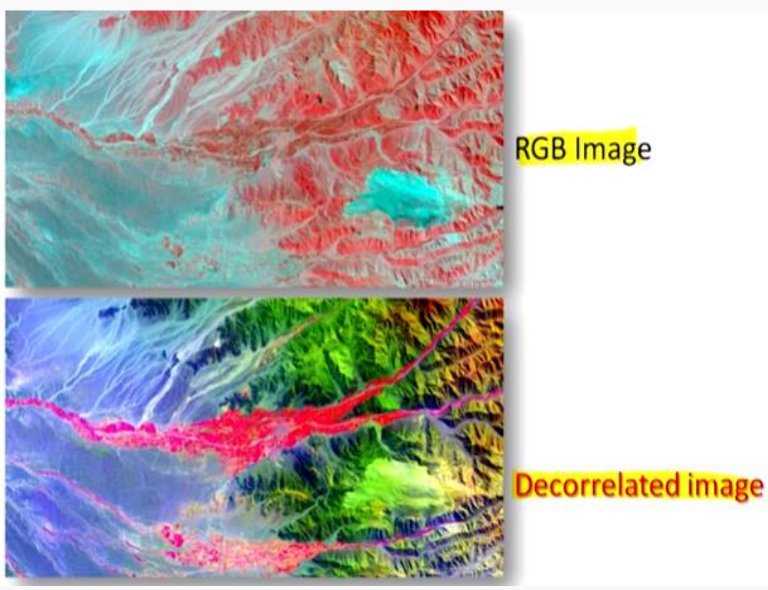

Example this is simple RGB image having of coarse 3 bands here now this is example from land sat TM. Now there are 6 bands have been taken for the analysis 3 components have been created these 3 components have been de-correlated again principle component 1, 2, 3 and after that a color composite have been created and this is what is de-correlated image. Now see that what kind of you know the variation it has created among pixel values for better interpretation and distinguishing different objects very easily as you can see in the just you can see the large differences between simple RGB false color composite and the de-correlated image.

Of coarse color scheme will definitely change one has to care about that while doing the interpretations but it is bringing many features very clearly which is otherwise was not possible in simple RGB image or false color composite image. So this brings to the end of this discussion and we started with just to recap everything or summarize. We started with the you know this band ratio things and before that time spatial filtering 2, 3 types of filtering high pass, low pass filter, edge enhancement and directional filtering.

And then edge enhancement and high pass are same but in edge enhancement you take generally a large convolution matrix then we discussed the band ratios, band ratios composites also and then we discussed the NDVI how to assess the health of the vegetation using remote sensing data this is a very standard thing at global scale it is being done regularly and since now we are having more than 48 years of data available and so therefore people are also using NDVI as indication of indirect effects of global warming and climate change.

So those kind of studies are also being done using NDVI images and then we also discussed principal component analysis and finally we discuss about de-correlation stretch. So this brings to the end of this discussion thank you very much.