Introduction to Remote Sensing
Dr. Arun K Saraf
Department of Earth Sciences
Indian Institute of Technology Roorkee
Lecture 13
Geo-referencing Technique

Hello everyone and welcome to this 13th lecture of this course on introduction to remote sensing and in this particular discussion, we are going to have a discussion on georeferencing technique. This is very important processing both in digital image processing that is means in remote sensing as well as in GIS. This is a common thing which has to be done to all types of datasets which are not so far belonging to geographic domain and that is why the georeferencing is very much required. It is a serial processing or a step by step it has to be followed and it's not a complicated but it is very important technique in remote sensing as well as in GIS.

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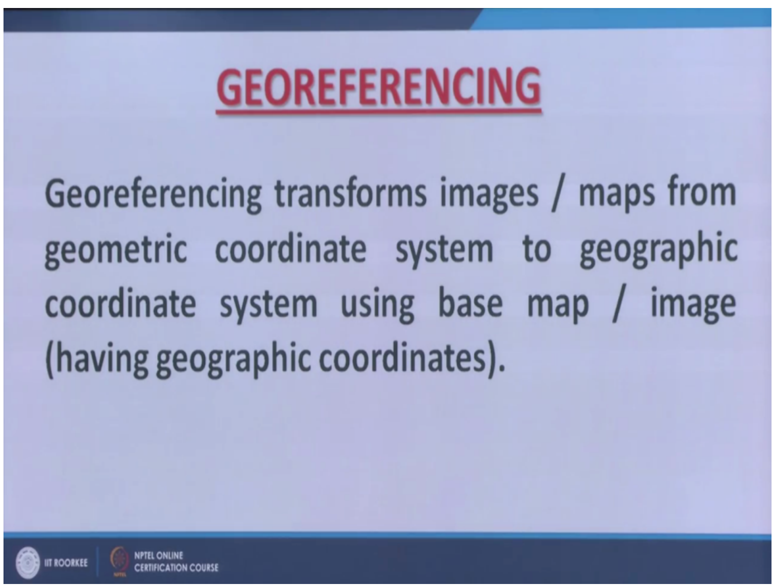

So if I look the definition, what is says is that the in the georeferencing, basically we transforms image, data, maps from domain, that is geometric domain to geographic domain. Geometric domain, if you recall the coordinate geometry which was taught to us in somewhere 9th, 10th class, introduced in 9th, 10th class that we used to have in the in the corner of 2 axis, in the origin, we used to have zero zero but I go to the downward or on the left side in my (co) coordinates then these becomes negative and then (the) complications will start once I go for measurement of length on any area or perimeter.

If I am having half coordination, positive half and negative and so and so forth so (geo) this coordinates is the concept is same, only this the coordinates have changed. Instead of having zero zero in the origin of 2 axis, we are having geographic coordinates which are continuous all over the globe. So we transform basically maps satellite images specially because those satellite images can be corrected to some extent using orbital parameters but those are not very good inputs for a very accurate geo referencing.

For relatively coarser resolution satellite images like NOAA AVHRR images, even these navigational or orbital parameters, if I use for georeferencing, maybe, for some applications may be appropriate but as we go for higher and higher special resolution, more accurate georeferencing in demand. Then we are looking for very highly accurate geo referencing process or technique and therefore we need to transform our satellite images, whatever they are coming from different satellites or maps because on GIS platform, we handle lot of maps also so these maps if I say a scan toposheet, a survey of India topographic map of a say 50000 scale.

Now it will have the image will have at the top left corner, will have 1-1 basically the from first pixel and then everything whatever it is there and this will remain in geometric domain unless we go for georeferencing. So that is why all these maps, if they are scanned, they will be in geometric domain, images also more or less are in geometric domain, specially high resolution images I am talking and we need to transform from 1 domain that is geometric domain to geographic domain and this georeferencing technique will allow you to bring coordinates in our images or in our maps of geographic coordinates that is in terms of latitude, longitude so this is the basically purpose of geo referencing.

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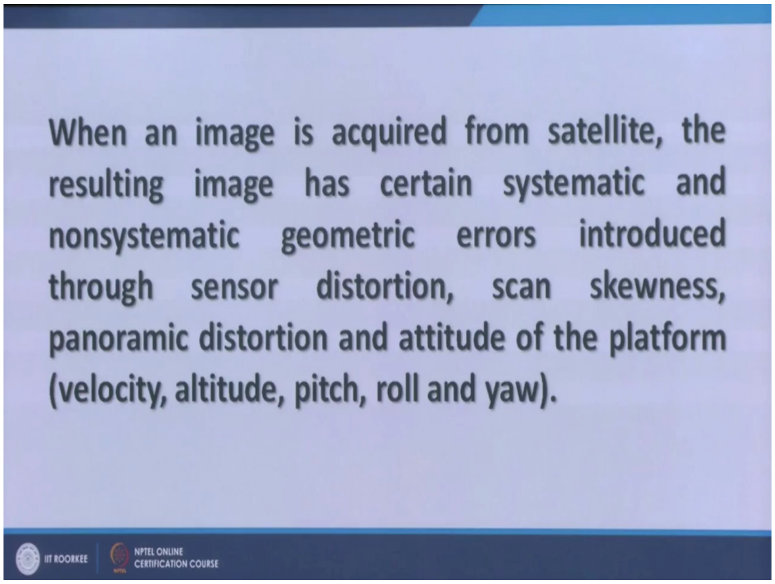

As I have mentioned that when a image is, a satellite is acquired, the resulting image has certain errors, systematic and nonsystematic errors. Very very soon we will be seeing which are systematic errors, which are non systematic errors and then (geo) the geometric errors will create distortions in the images. These distortions in the images might come because of the scan skewness. Scan skewness comes because your polar orbiting satellites or remote sensing satellites are not exactly orbiting from north to south, they are having a near polar orbiting and therefore and at the same time, when the scanning is (one) is done by the sensor or a satellite based sensor, earth is also moving.

So therefore there you will have a skewness which we will see very soon what the basically skewness is. Maybe a panoramic distortions are because your satellite having say relatively poor spatial resolution data might be covering a very large part of the earth, that means the swath width, if it is large then the curvature of the earth will also play a very important role and then your images might be getting distortions because of panoramic distortions.

May be attitude of platforms, these satellites are moving objects in a space so sometimes there might be a change in the velocity, they might tilt in 1 direction or another and therefore they might bring these kind of errors in the data like velocity, altitude, pitch roll or yaw, all kinds of errors are inbuilt in images, in satellite images but using 1 geo referencing technique, many of such errors, especially systematic errors can be removed quite easily. So that is that is the beauty of this technique.

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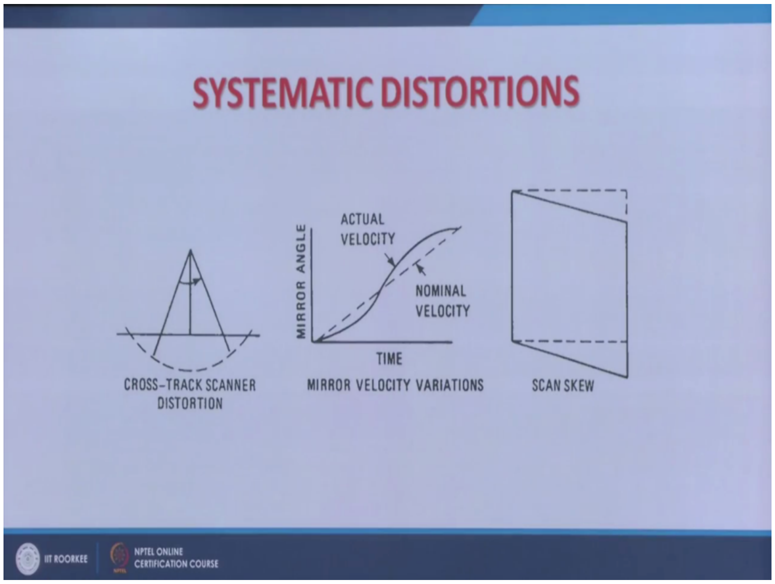

Few systematic errors which are easy remove, systematic errors, across track scanner in earlier like in a Landsat programs, we had across track scanners so they used to have distortions in the images, specially on the edges of the image so that was the reason. Now we are having more linear arrays system based along track scanners and therefore these errors have anyway have been minimized.

Then mirror velocity because in these errors, we use to have optomechanical devices as discussed in earlier lectures when we were different sensors and platforms so they used to have moving mirror and that (mov) a mirror used to have some variations in the velocity which might cause some distortions in the images so in the earlier versions of this Landsat MSS images, all these kind of errors were there.

A skewness problem will also be there as I have mentioned that when satellite is orbiting not in near pole to pole but near polar, same time earth is also moving and within that 1 say a scene is a about say a 10 minutes are required to capture a scene of say 150 kilometer by 150 kilometer area by a moderate resolution sensor, then in that 10 minutes, there will be some movement of the earth below the orbit and therefore this will cause a skewness and that is why you see in the images.

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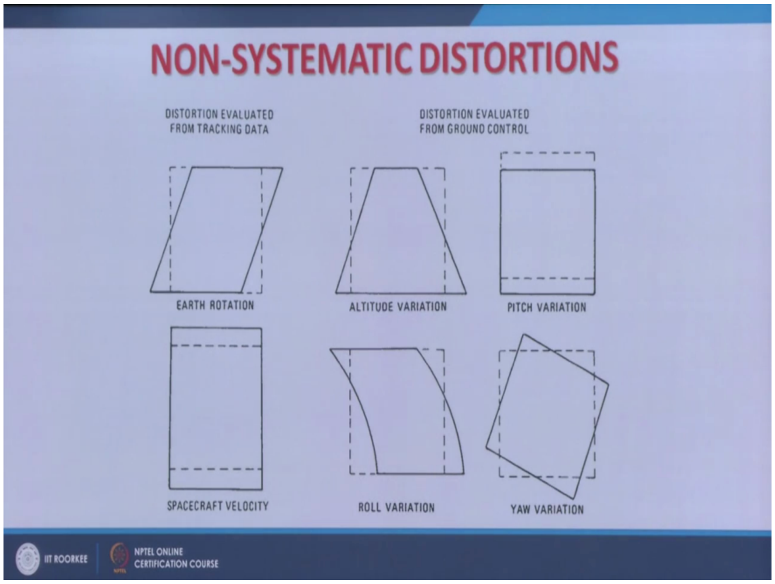

The non systematic errors which are which are difficult to predict and which might be there, sudden change in the earth rotation of course this is more or less an known thing but altitude variation of the satellite, pitch variations of the satellite, a spacecraft velocity, suddenly it has changed, (salol) slowed down, it may create some problem, role that means the the your platform has a rolled over like this this kind of a movement so that will create a rollover or yaw means it has moved something like this in a space while moving or while scanning or acquiring the satellite image. So therefore these kind of errors might be inbuilt in the data so many of these errors through georeferencing can be removed quite easily.

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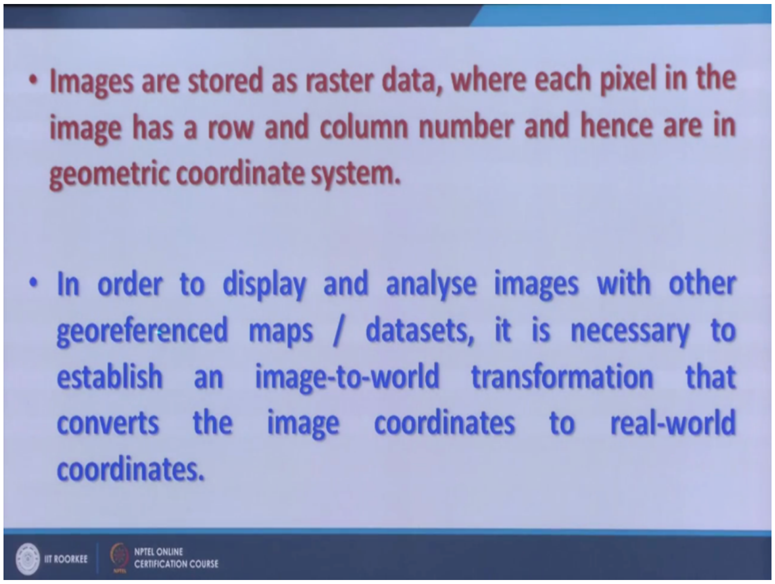

As you know that images are stored as raster data that means the 2 dimensional matrix which each pixel in the image has a row and column numbers are hence are in geometric coordinate system. So top left, we start counting top left, the first pixel first row and so on so forth. And in order to display and analyze these images in digital images processing or on GIS platforms we need to have georeferencing maps or datasets. That means we need to have at least some there for referencing, something for referencing and that necessary to establish an image to word transformation.

So we need to have a master image or master map and then if I use a word sleve the map which is in geometric domain, the image which is in geometric domain needs to be transferred into geographic domain so that you need to have something to which is already in (geo) (re) referencing or (ge) geo reference or geographic domain and so this this image to word transformation is possible and then your image can be converted, image coordinates which are row and columns can be converted to in real word coordinates that is, that means the geographic coordinates and that means the latitude and longitude.

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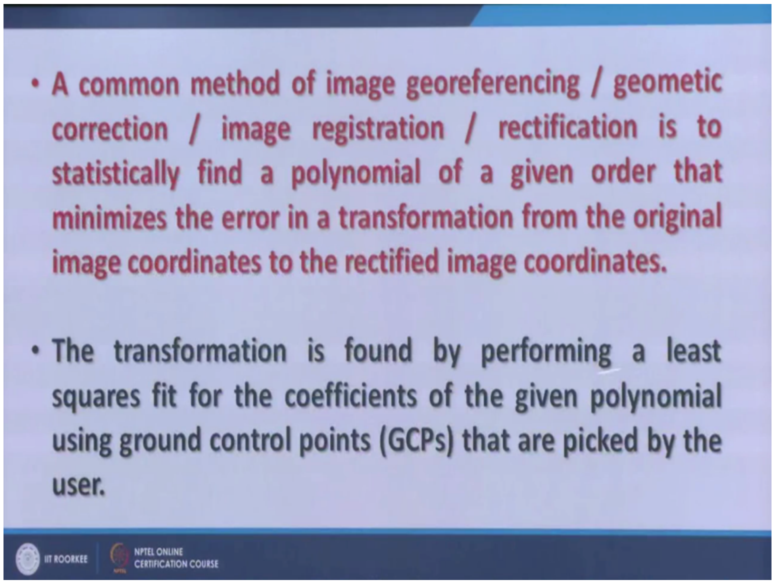

So a common method of a geo referencing, also it is known as geometric corrections, an image registration, image rectification, so in different books, literature, you may find little different terms. Nowadays, the most popular term for this kind of processing is called georeferencing is to statistically finding polynomial of a given order. Depending on the distortions which you are expecting on an image, you would choose appropriate polynomial equation and then this that will minimize the errors in a transformation from a original image coordinates to rectify image coordinates.

We will see little later all these details and then once these transformation function is found that which pixel has to go where then the next thing is to we go for the least square fit for a coefficient for a given polynomial equation, using ground control point that are picked by the user and once this is there, the transformation is there then the last and third step is that you go for georeferencing.

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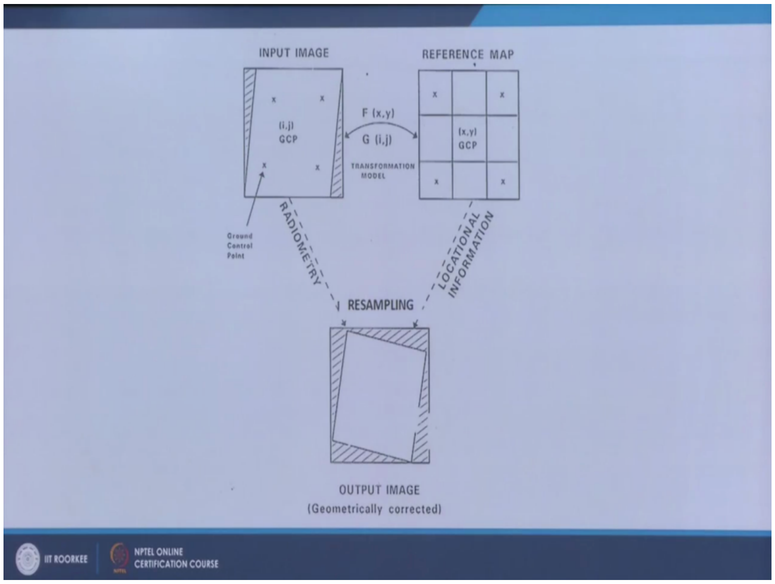

Let me give you through this schematic that this is input image which is already in geographic domain that is it is georeference I consider as a master image and this is sorry this is my reference map, master image, this input image which is having a skewness effects are visible here so this is raw image, this is master image. Now, these are the ground control points, what are the ground control points? Ground control points are those points which are common visible in both my image and say in a map.

So suppose if I say this is my survey of India toposheet and this is my satellite image so if I am seeing the crossing of 2 roads or maybe a bridge on a river, may be a bridge on a rail rail track or aqueduct or similar kind of structures, which are fixed which are not moving with time very quickly so these may become my ground control points and we say common ground control points. It means if I am seeing a roads of 2 roads cross section here then the (sa) corresponding road cross section should also be visible in my map so I will note down the coordinates from my master map or a reference image and then use and assign these through my polynomial equation, assign these to these unknown location which I have already identified but only coordinates are missing.

So this image will have (geo) geometric coordinates, it will start from top left, this image, master map will have my coordinates, geographic coordinates which might start from bottom left. And once it is done through resampling then I will have which this this raw image will will fit over my master map 1 through after doing resampling and then finally I get a product which is geometrically corrected, that means it is now having geographic coordinates in it and it can be used on a GIS platform, it can be pasted on Google Earth and so and so forth.

Now which order, polynomial order to choose but before that, let me retreat 3 steps, first step is registration, registration of an image or a map which is slaved with a master using ground control points. Once this is done then I choose once it is registered, as per the my polynomial as per the requirements, as per the distortion present in the image or expected distortions, I will choose accordingly the polynomial equations and these polynomial equations with least square fit will give us the transformation function.

Now transformation function means that which pixel will move in which direction and how much and once I know this much for each pixel of my slave image, with a reference to master image then the third and last one is georeference and resampling and that (mea) there are 3 techniques of resampling and then the value of the pixel, what values then should be assigned to a empty master map which is going to be my final georeferenced map or image and that can be decided by during the resampling step so 3 steps (furth) first the registration using ground control points (equ) then using polynomial equations, finding out the coefficient or transformation function and finally going for resampling.

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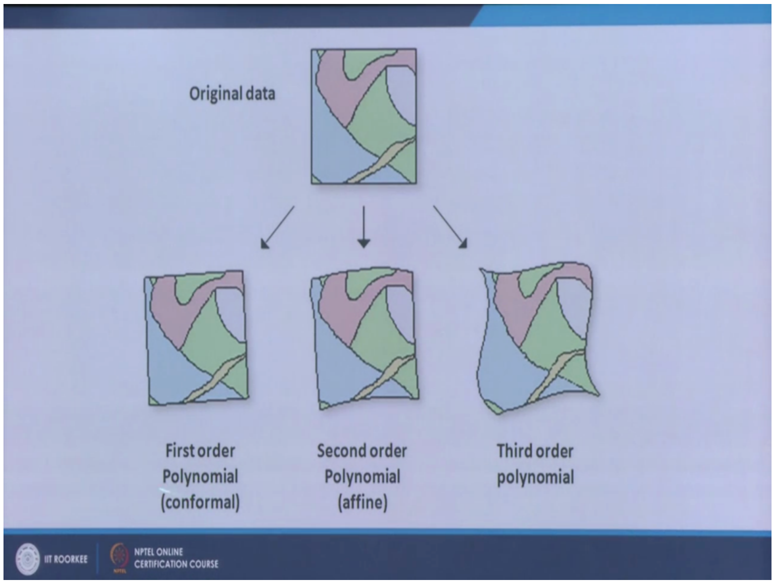

So now which polynomial equation, the first order polynomial is required which is also called as conformal conformal polynomial. when I have to transform from just simply from geometric domain to geographic domain so suppose I am having a a map which is not yet georeferenced, I just would like to simply transform without change in a scale without any rotation or without any (da) you know removing curvature of the earth or anything, just simple transformation from geometric domain to geographic domain then first order polynomial would be more than sufficient for this kind of transformation.

But in case of satellite images, this is not sufficient at all because it involves not not only just simple transformation from geometric to geographic domain but might be change in a scale, might be a rotation as well so if that kind of a requirement is there then the second order polynomial will be chosen, that is also called a fine transformation so a instead of just transferring from 1 domain to another, second order polynomial equation will allow us to transform not only from (geo) a (geometric) domain to geographic domain but also it will allow us to change the scale and it will allow us the rotation of my map so then I that north completely upward so that for that purpose, the second order polynomial will be chosen.

If I am having a relatively coarser resolution data and this satellite image requires corrections not only not only the transformation, not only change in a scale, not only rotation but same time this curvature effects has to be removed because satellite image is representing a curve surface of the earth if it is a coarser resolution image. For example NOAA AVHRR data which is covering a 2800 kilometer in 1 swath, 1 go and this width of an image is covering a (curvat) curved part of the earth and that has to be unwrapped. Basically it has to flattened and therefore for such kind of images where we expect that they might be suffering from even few more distortions, not only scale change and rotation then third order polynomial is appropriate.

Though in some softwares in image processing or in GIS softwares, people have implemented up to 12th order polynomial order but I don't think that a such kind of a geo--referencing is required because maximum what we can see the distortions is all because of curvature of earth or the rotation of a platform, yaw and roll, other things are there or there is a skewness, all these can be corrected at third order polynomial, but if you if you higher in hard higher in the polynomial equations for determining the (fin) the transformation then the number of GPs will require would be much higher.

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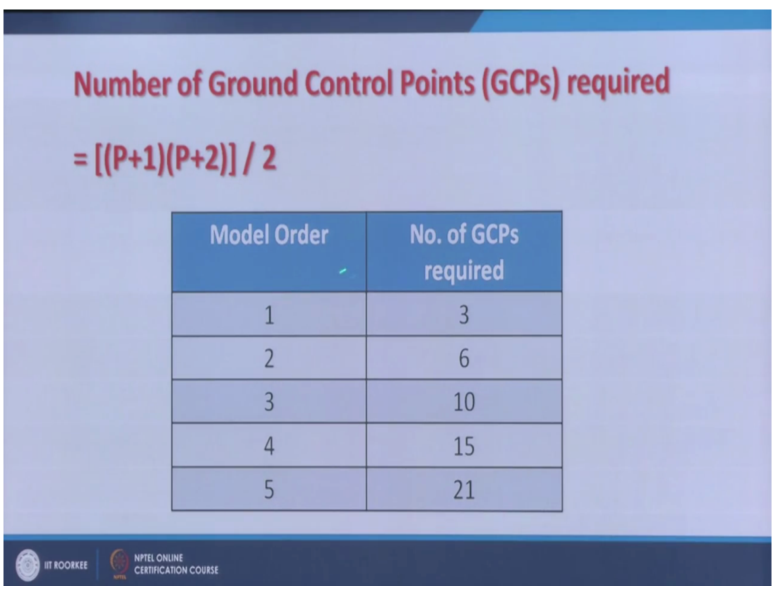

So this is decided based on the ground control points and the there is, and based on this equation, P is the polynomial equation so if choose for first order of polynomial then number of GPs, minimum number of GPC, GCPs are required only 3 but if I choose 2 then second order polynomial then I required 6. If I choose the third order polynomial then minimal order of ground control points are required 10 and so on. That doesn't mean that if I am going to for georeferencing, I will only choose if I am using the first order, I will collect 3 ground control points.

No, that is the minimum requirement, in practice we go by multiplying 2 so if I am going for first order polynomial, instead of 3 ground control points, I will choose 6. If I am going for second order polynomial, instead of 6, I will choose 12 because I I want to achieve georeferencing within pixel and for that, I need to choose ground control points very carefully and corresponding point in the my salve map, 1 and then I should choose more ground control points so that my image rectification becomes very accurate.

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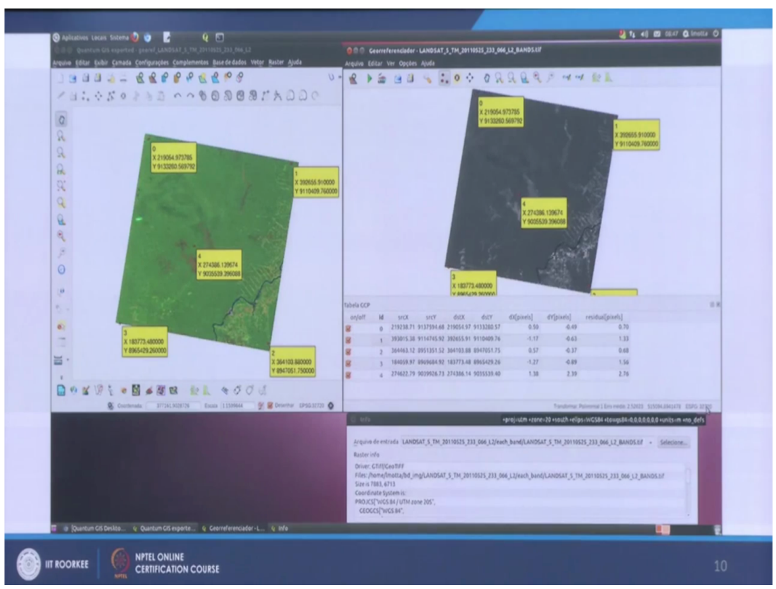

This is how, once again I am trying to explain here that a 1 map here is the my slave map, another one is my master map. Now, I am slowly slowly I identify these ground control points. 1 thing which you will notice here is that these ground control points are spread all over the image. Just 5 ground control points are demonstrated here but what basically means that (the) if my image is this much, I should choose ground control points which are through, which within which are throughout the my image area. It is not that all ground control points will be concentrated only in 1 corner of an image then it will give you a completely wrong georeferencing.

Let me give you analogy, so basically you treat the satellite image or digital image as rubber sheet so if I have to fix this rubber sheet over a surface then I will nail or put a tape on 1 corner then another corner opposite direction then (ather) another 2 more corners on opposite direction then in between might be that rubber sheet may not be fitting very well. So again I will use few more tapes or few more nails or few more GCPs, ground control point so it uniformly is a my GCPs are distributed and I get best fit so that is why you know these ground control points should be spread all over the image and rather than concentrating in just 1 area so number of ground control points, one should go multiplying by 2.

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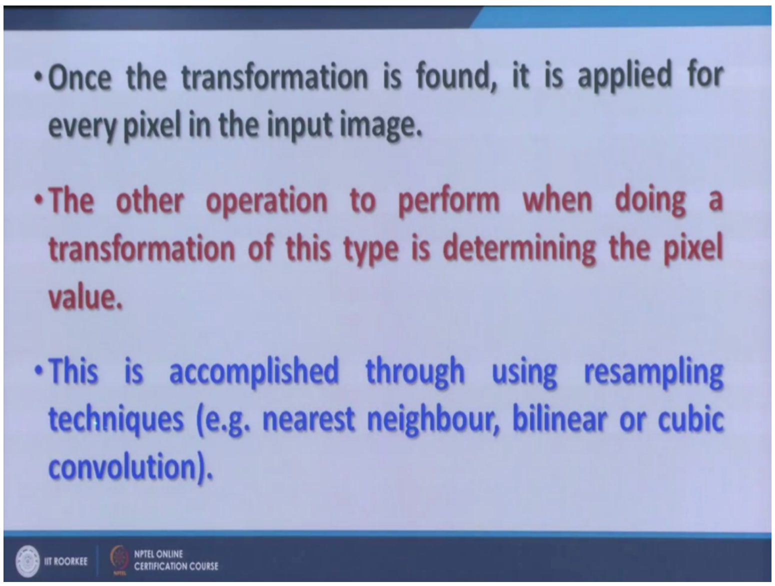

So generally we go for third order of polynomial equations, minimum 10 points choose 20 and the advantage nowadays, because of these this technique is becoming very user friendly both in digital image processing in GIS software's so once you choose 2 or 3 initial ground control points, the system itself starts predicting about as soon as you go for the 4th, the values, this means the coordinates it will predict and it is sometimes quite good so one more important thing that initial ground control points which you choose.

You should have a very high level of confidence in it so whenever you are going for georeferencing, make sure that first few initial points, they should be a very far apart to from each other one and they should be highly reliable ground control points. You are having full confidence that you are rightly identifying that ground control point on the image as well as on your master map so once you are having confidence of that level then these the software's which will predict for future ground control points, the and the geographic values are going to be very accurate and then later on, your whole process will become much much easier.

The maximum time the software will take or in this in this technique, the maximum time should be spent to collect very nicely very accurately the ground control points because then next 2 steps are has to be done by the computer and nowadays it's not very difficult, it is very quickly you can do it then so you must spend lot of time so that you very correctly, very accurately you or precisely you collect these ground control points.

Once the transformation is formed through these polynomial equations is applied for each pixel of the input image so after the ground control points then you choose the appropriate polynomial equation, say I have chosen the third order, I have collected 20 points, now I am having a also at the same time, I will have error table also. In these software's, you will get error table so you would know exactly that which ground control point is giving better accuracy or having more error. So the point which is having maximum error, I may reconsider it, means I may remove it and recollect it. In that way, I can further improve my geo referencing so this these tables are used to assist my accuracy part of my registration through using these ground control points.

Once I am okay with that then I go for this (tranfo) transformation function. The other operation to perform when doing a transformation of this type is determining the pixel value, that is the resampling, the third step, last step in georeferencing and this is accomplished by using these resampling techniques, there are 3 types, nearest neighbor, bilinear and cubic convolution, we will discuss all these 3 one by one.

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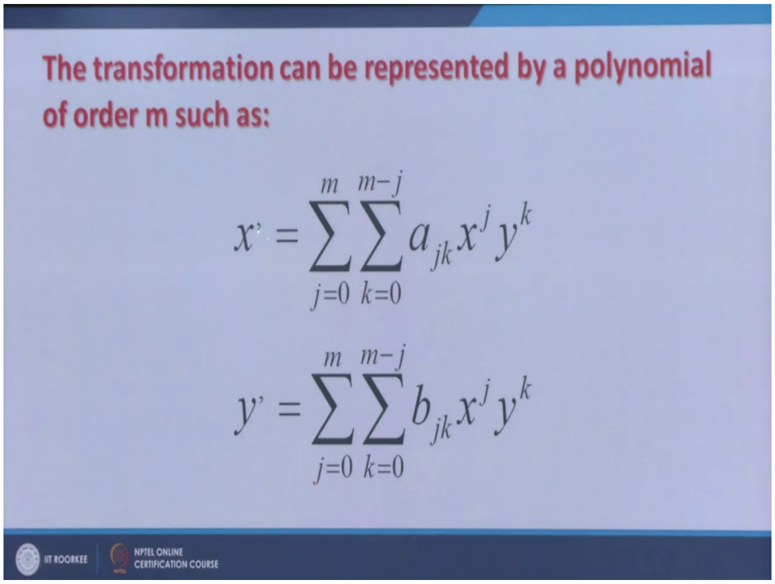

So the transformation can be represented by a polynomial order. This this kind of this is a generalized polynomial equation (and) as per given order, you can calculate or estimate the X and Y for your the slave image for that corresponding ground control points.

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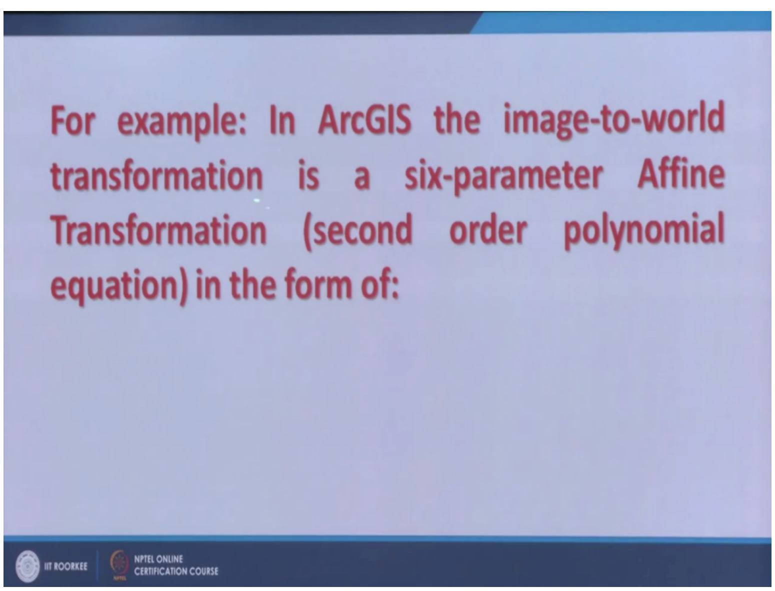

And then once this is available then like for example I am giving (so) example from ArcGIS software that is the image to word transformation which is a GIS software is to 6 parameters a affine transformation, that is the second order polynomial equation in the form of these equations very simple one and I will describe all these one by one these equations.

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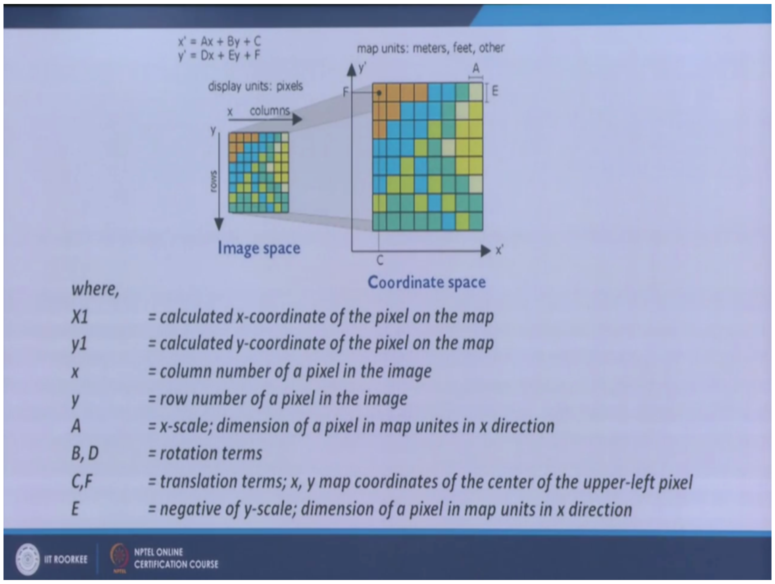

That here is the image and the here is the master image, here is my slave image and this in equation, the X1, X1, the calculated X coordinate of the pixel on the map and this is Y1, the calculate bicoordinate on this one and then X and Y are the column low and row number of my input image and these are of my target map and then I having A because the second order polynomial also will allow me to transform. Not only transform from geometric domain to geographic but will allow me to change a scale.

So in the my equation, I am also having A that is scale dimension of a pixel in a map units in X direction then I need to have B and D and that means the rotation terms because if the second order polynomial also allowing you to rotate the image, not only allowing us to change the scale, not only transforming from geometric domain to geographic but also rotation and then C and F are the translation terms, that means X and Y map coordinates of the center of upper left pixel.

And then also one more thing is the negative of Y scale because remember I mentioned that in a slave map or an image scanned map or an image, the (geo) the coordinated starts from top left whereas in a a geo reference map, the coordinates will start from bottom left and therefore this negative of E is (al) plays also a very important role on Y scale that is dimension of a pixel in map unit in X direction so that has to be also accommodate in my scale.

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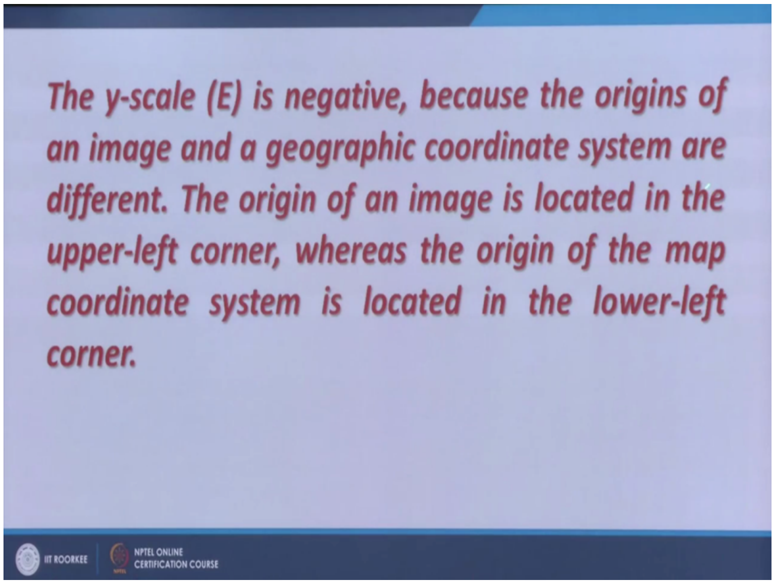

This Y scale negative as I have just explained to you is because of the origin of an image and a geographic system are different and the origin of image is located in upper left corner whereas the origin of a map coordinate system is located in the lower left corner.

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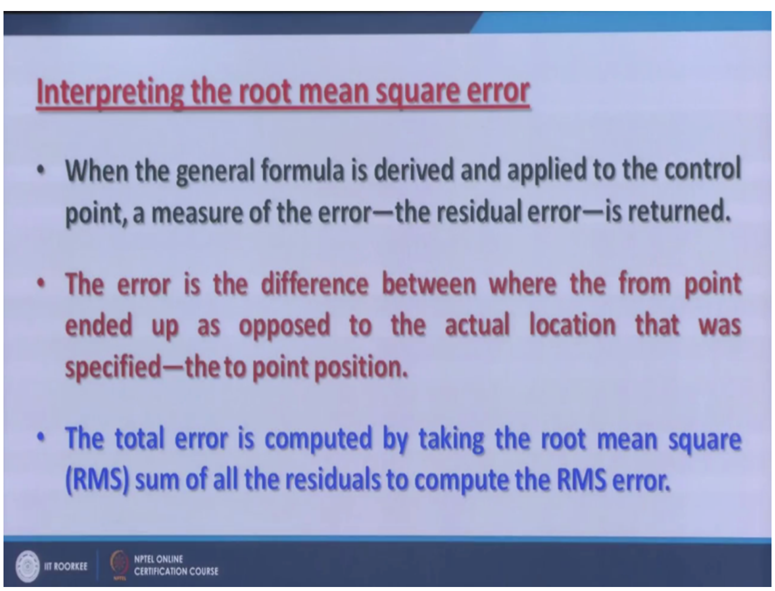

Now a we about interpreting these errors which we have while when once we choose the appropriate polynomial equation, we get the error estimate. So how how you choose these errors is that the when when the general formula is derived, they apply to the control points, a measure of error, that is residual error is written and this error is nothing but the difference between where the point from ended up as opposed to the actual location that was specified to the point position and the total error is computed for each GCPs error is calculated for total it is also.

Total is also useful because we we would like to see whether I am within a 1 pixel depending on the spatial resolution so if I am (have) having a 50 meter resolution data then I need that my error in mapping a scale should be less than that, this total RMS. Root mean square error and if I am getting that error which is less than say 50 meter then I am sure that I am having within a pixel and that's the best because pixel is nothing but a unit and a unit means individual, individual and I cannot go beyond that. So if I am achieving or this error within 1 pixel, I am achieving quite good georeferencing.

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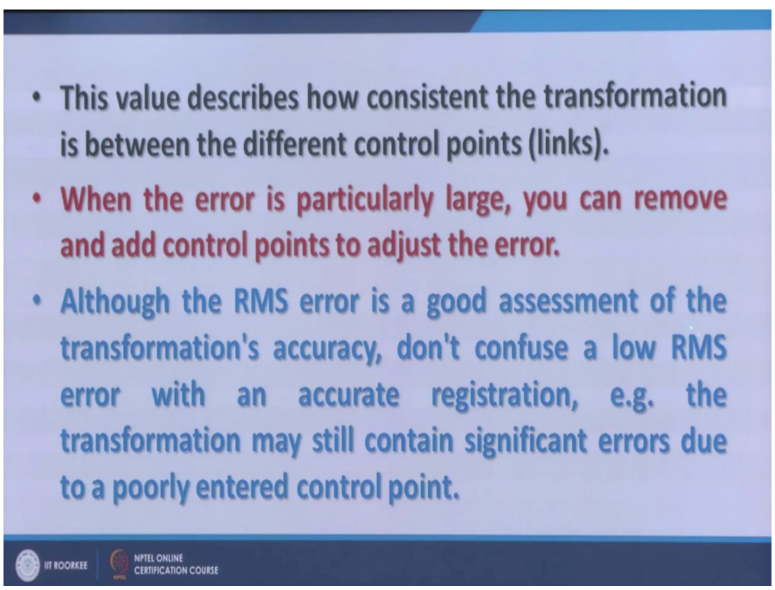

So this value, error value describes how consistent that transformation is between different control points. Also in some software's like an RGIS, this difference is also called links and while when you will do in such software's, these links are shown with a color so if it is coming green, that means your link is good. If it is coming in red, that means that particular GCP, you have wrongly collected and therefore it is showing more errors and when the error is particularly large, you can remove add a control points to adjust the error so it's a continuous process and once you have collected say 10 points, now you look for individual points and corresponding errors.

The point which is giving maximum errors you may remove it, again recollect it and if it has improved then look that which point is giving the maximum error and likewise you can keep improving till you reach within a pixel. And although RMS is a good assessment of the transformation accuracy don't confuse a low RMS error with an accurate registration because when for example the transformation may still contain significant errors due to a poorly entered controlled points.

So remember this thing if you have collected controlled points only in a corner of an image then you will get a small RMS errors and you will think that I have achieved a very good registration using control point but in fact not so that is why I have mentioned that your ground control point should be spread all over your input image.

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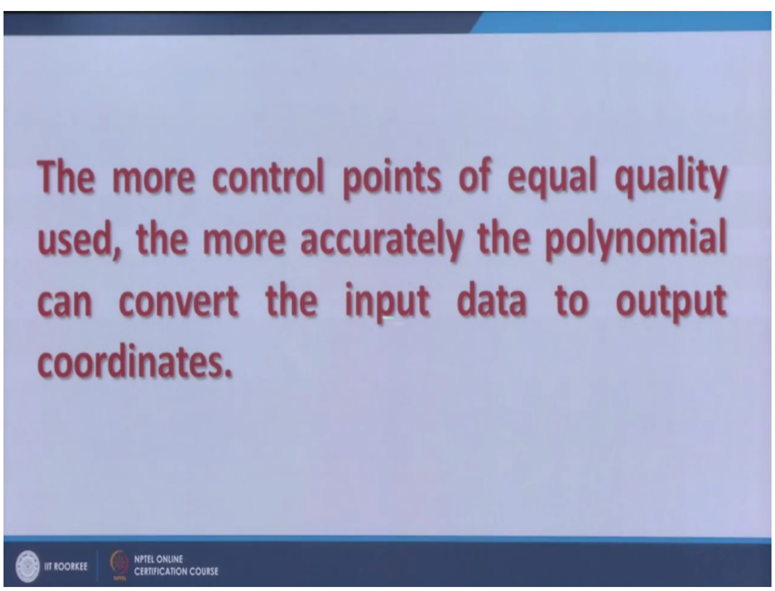

More ground control point, that is why I mentioned, then multiply by at least factor or 2. So more ground control points of equal quality means highly accurately collected with high level of confidence that yes these 2 road crossings is the same as I am seeing in satellite image as in my map, master map and you used for accurately, the polynomial can convert the input data into output coordinates. In the previous lecture, I have mentioned that nowadays the Google Earth has become more or less a standard product and for high resolution satellite images, the ground control points, we can also collect from Google Earth, by zooming it and once I am sure that is the corresponding point which I am seeing in my raw image yet to be georeferenced, I will collect those coordinates X and Y and put against my image.

So in that way, I may achieve a much better georeferencing, there are other ways also. I can go in the field, I have identified these ground control points initially on the my satellite image, I will go in the field, collect my ground control points coordinates very accurately maybe using even differential GPS. So once I have collected ground control points, really on the ground, their coordinates then my level of confidence in my geo referencing is going to be very high.

These are required, once we go for a very high resolution spatial data or very high resolution satellite images but if you are using relatively coarser resolution satellite data, probably going in the field and collecting ground control points or coordinates of ground control points may not be required. So whatever available resources, you can use especially the Google Earth and some master maps already georeferenced satellite images and then can collect the GCPs, corresponding GCPs and can get the geo referencing done. So this will convert into output coordinates.

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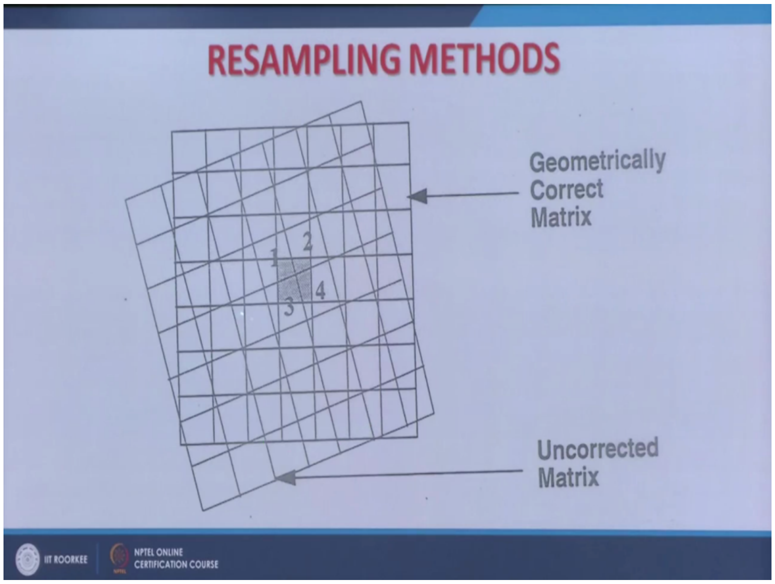

Now the last step in geo referencing, that is resampling. As I said that there are 3 techniques in resampling but in simple 1 we view graph, I can explain to you all 3 and think that this is going to be the the one which is in mentioned here is geometrically corrected matrix. This is yet empty matrix, means after knowing the transformation function, now I know that this a particular has to move say for example pixel 1 which is marked on uncorrected matrix has to be moved in the shaded area of a corrected matrix. Then what should be the value of pixel, one is the location of pixel, where it has to move and how, what is going to the value?

Whether original value I am going to keep or I am going to change the value. Why the change is required we will see once we go in the second and third resampling technique. In the first resampling technique, that is the nearest neighbor in which what we do that the whatever the value pixel 1 having, suppose it has it is having a value and in a 8 bit image, it is having value of say 150. Now, I will have I will have a the system will have a look that a which out of these 4 which are overlapping the shaded pixel, which one is having the maximum overlap. What I will find that the pixel 3 on this uncorrected image or matrix is having maximum overlap on my target pixel and therefore it would have the whole weightage.

That means the (an) the pixel value say 3, whatever 3 is carrying may be 200 will be directly transformed to the shaded pixel of my corrected matrix. So the pixel which is having the maximum overlap will have the full influence and this may be achieved in the resampling which we term as nearest neighbor. We will see little more details about this. Let's go for the second one that is bilinear in which what is done that as you have as you have seen that the shaded pixel is having overlap uncorrected image marked 1, pixel 2, 3 and 4 having overlap of different size of areas like 2 is having minimum, 3 is having maximum and 1 and 4 probably of having same.

So now I can use the weighted average concept and say that the pixel whichever is having the maximum overlap will have the maximum while calculating the pixel value of my target cell or target pixel and the pixel which is having less overlap or minimum overlap will have the minimum weight and therefore it will have less influence on the target pixel.

So in this particular example, the pixel 3 of uncorrected matrix will have maximum influence over this shaded pixel then pixel 2 which is having minimum. So all 4 pixels as per their overlap will have their weight while calculating the pixel, the value of the target pixel and this technique is called bilinear.

Now remember when we started with nearest neighbor, only the pixel which had the maximum influence carried the whole value but here now 4 pixel are involved and therefore you have to think at the same time what is going to happen to the image quality. On that, I will come little later but let's discuss the third resampling technique and that is your cubic convolution. So in which instead of involving 4 pixels, now, 4 by 4 matrix, all surrounding pixels, even the far distance pixels will be used on distance weighted average.

So the pixel which are having maximum overlap and the minimum distance will have the maximum say while deciding the pixel value of the target pixel and the pixel which is very far, having large distance no overlap will have a minimum say while or minimum influence while deciding the pixel value and this kind of resampling technique is called cubic convolution.

So if you compare with nearest neighbor with cubic convolution, you would realize the too much averaging of a pixel is done for target pixel using 4 by 4 that means 16 pixels are involved to determine a pixel value for a target pixel but at as per (dip) as per requirements, these 3 techniques may be chosen but if you are only looking for highest quality of image, don't want to compromise on the quality of the image then the nearest neighbor would find the best combination.

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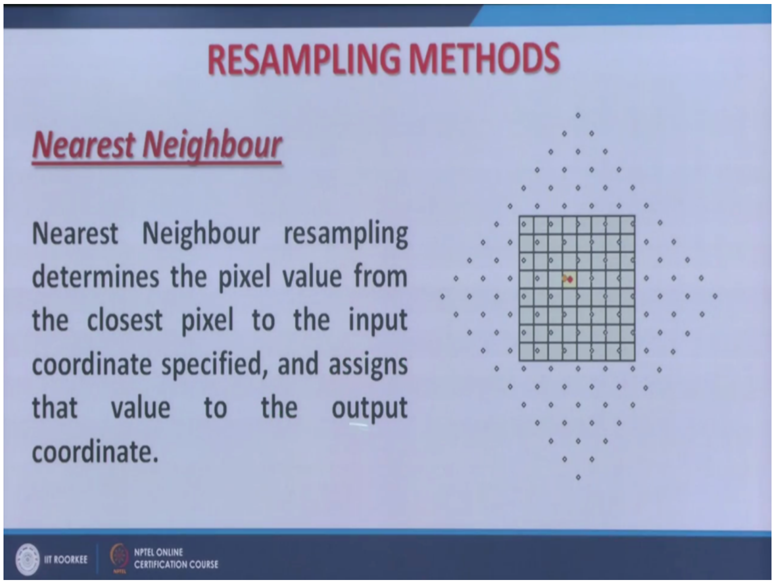

So in nearest neighbor resampling we determine, as I have mentioned the pixel value from the closest pixel to the input coordinate specified and assigned that value to output coordinate and or output pixel so the pixel which is having maximum overlap will have the entire say entire influence.

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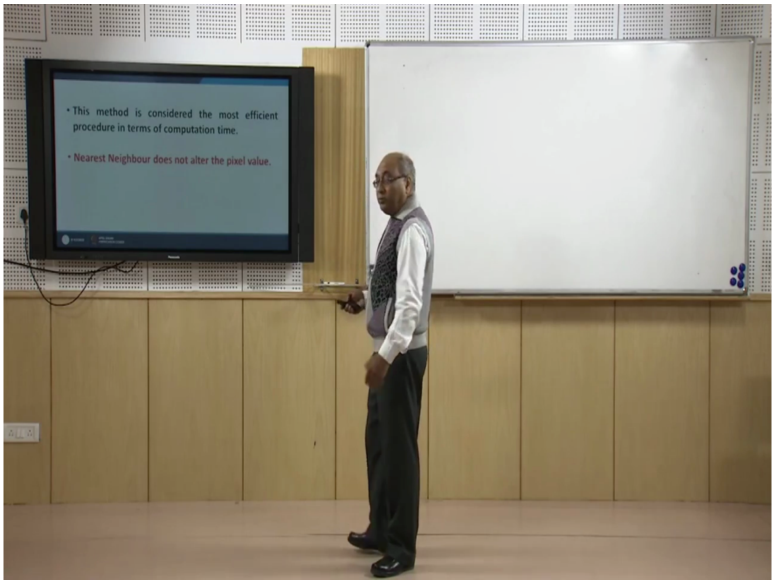

This method is considered the most efficient procedure because it doesn't have to look the other 4 pixels then weighted average calculation or other thing or like in cubic convolution, 16 pixels are involved, their distance is measured, weighted average is calculated, then a new pixel value is found so that much of calculation is (net) not required that is why it very efficient nearest neighbor in terms of computation time.

Nearest neighbor does not alter the pixel value, especially when you are going to use these georeferenced images for image classification, the nearest neighbor is going to give you the best output while you for classification because if you go for cubic convolution and then classification, you may introduce some errors during classification so in that way, this technique is also good looking for the future use of that particular image which you have just georeferenced so nearest neighbor will not alter your pixel value.

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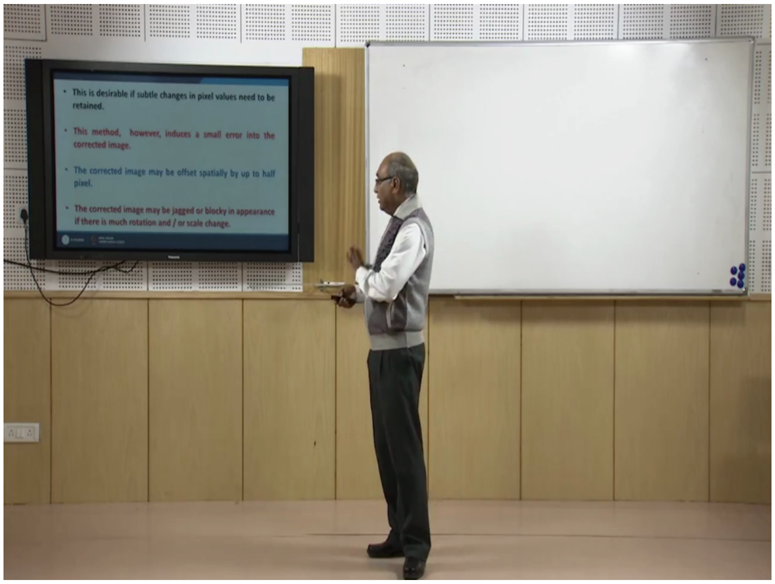

If desirable, it is subtle changes in the pixel values need to be retained then you go for nearest neighbor and this method however induces a small error into the corrected images especially it is might be offset spatially by half pixel because there might be some a stairsteps kind of or staggered staggered appearance in the image because you you are just lifting a pixel value and assigning to another pixel without considering the neighborhood. And the corrected image may be jagged or blocky in appearance if there is a much rotation or a scale change is there so if it is a simple transformation from geometric to geographic that means first polynomial order then there may not be any complication.

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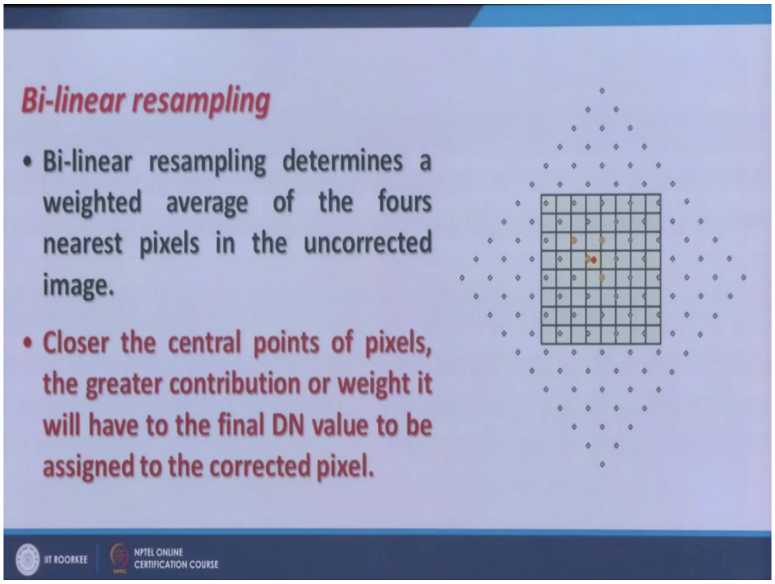

Now bilinear the second one as mentioned that determines a weighted average average of 4 nearest pixels in the corrected image and these 4 pixels are involved and the closer the center point of pixel the greater contribution or the weighted will have for the final digital number or pixel value to be assigned to corrected pixel.

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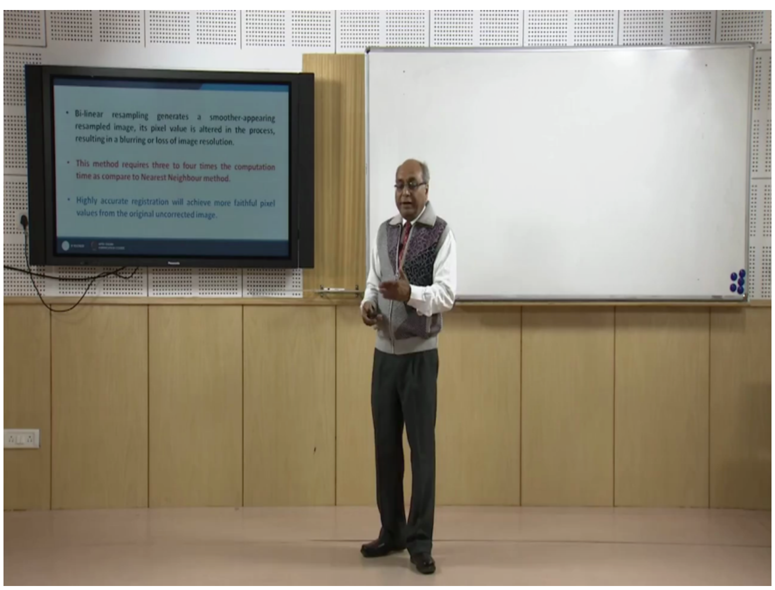

And this way the bilinear sampling, generates resampling generates a smoother appearance resampled image compared to a nearest neighbor. The pixel value is altered in the processes because now 4 surrounding pixels or overlapping pixels have put their influence while determining the pixel value for the target pixel resulting in a blurring or loss or image resolution so as I mentioned, if you are going for very accurate, looking for very accurate image classification then perhaps nearest neighbor might be good.

Even bilinear can work but cubic convolution may not give that kind of good results but it will have a very smooth appearance and this method requires 3 to 4 times the computation time as compared to nearest because the nearest method, once the maximum overlap pixel is found, that value is assigned, no calculation but here weighted average has to be calculated using 4 pixels and therefore computation time is going to be 4 times. Highly accurate registration will achieve more faithful pixel values so if your first step is very accurate then you will achieve better results in the last step.

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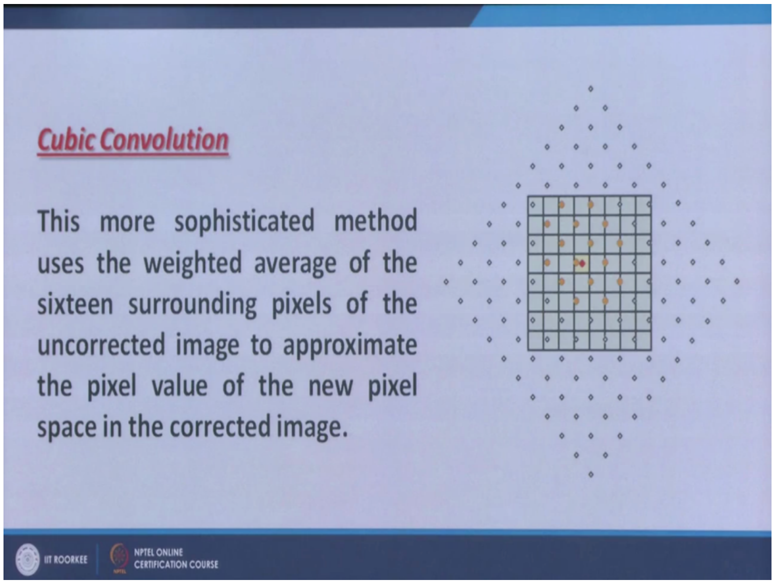

And last one in this resampling technique is cubic convolution and the this is more sophisticated method because it involves the 16 surrounding pixels of uncorrected images to estimate the pixel value for the target pixel and therefore of course it is going to be much more compute intensive.

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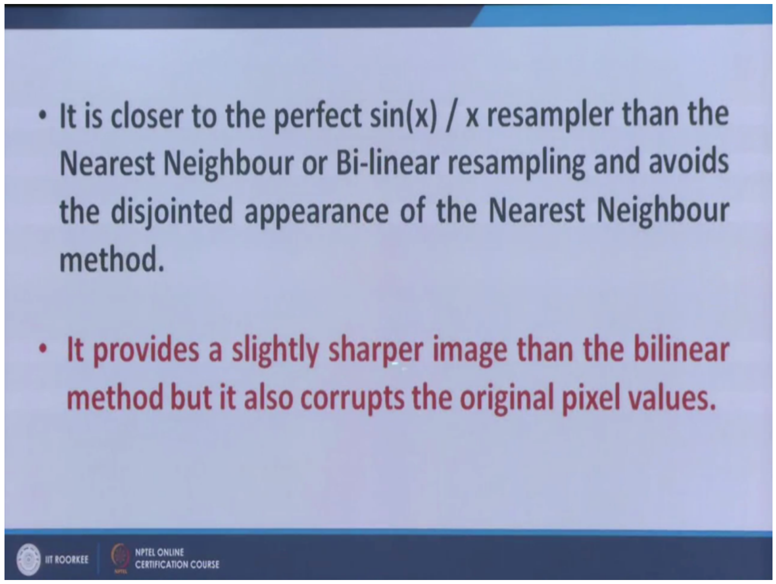

Then it is closer to the perfect Sin X over X resampling then the nearest neighbor or bilinear and avoids disjointed appearance and very smooth appearance as compared to nearest neighbor which will have a jagged stair steps (kan) kinds of might have. Whereas this will have this will have the cubic convolution provide the more smoother results but not may be not be appropriate very appropriate for images for which are which are going to be for classification. And it provides a slightly sharper image than bilinear but it also corrupts the original pixel value, altered, original pixel value is completely altered having influence of now 16 neighboring pixels.

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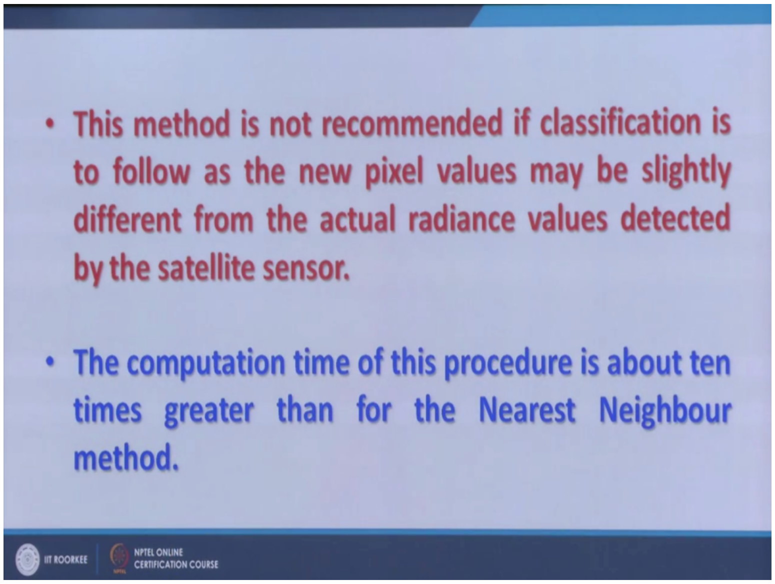

And this method is not recommended as I am mentioning the classification is for is to follow as the new pixel value may be slightly different than the actual radius values detected by the satellite sensor. And the computation time is going to be more than 10 times than compared to nearest neighbor method so this brings to the end of this georeferencing technique which is very important and common technique between remote sensing and GIS.

If all 3 steps are followed very carefully then one can achieve a (whi) very good I a georeferencing and anytime you can check your results of georeferencing by putting your images or maps which you have georeferenced on Google Earth so that if it fits with the surrounding, you are you are sure that you have done a good georeferencing so good luck, thank you very much.