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Digital Image Processing of Remote Sensing Data

Lecture – 08
Geo-Referencing Technique

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Hello everyone and welcome to this digital image processing of remote sensing data course, and in this lecture we will be discussing a very important technique which is geo-referencing and sometime people also call it as a major rectification another thing. This is a common technique between remote sensing that means in digital image processing and GIS, and very important one.

The purpose basically of the geo-referencing technique is to transform your image from geometric domain to geographic domain. Why it is required, because we know when image is acquired by a certain light sensor then it belongs to at that moment it belongs to the geometric domain. And then it does not carry the geographic coordinates like lattitude and longitude.

So in order to fit with other data sets, other maps and other things especially in on a GIS or image processing platforms then you require geo-referencing that means transforming from geometric domain to geographic domain. One other important thing which we will be discussing in the deal about the origin of animation, the origin of image that is the first excel they said define at top left corner.

So the first pixel is having first row and first pixel and which we count, we start counting from top left corner. Whereas, in case of geo-reference image it is the bottom left. So this also is very important and to understand, because when we go for this geo-referencing that also is incorporated while transformation is being performed.
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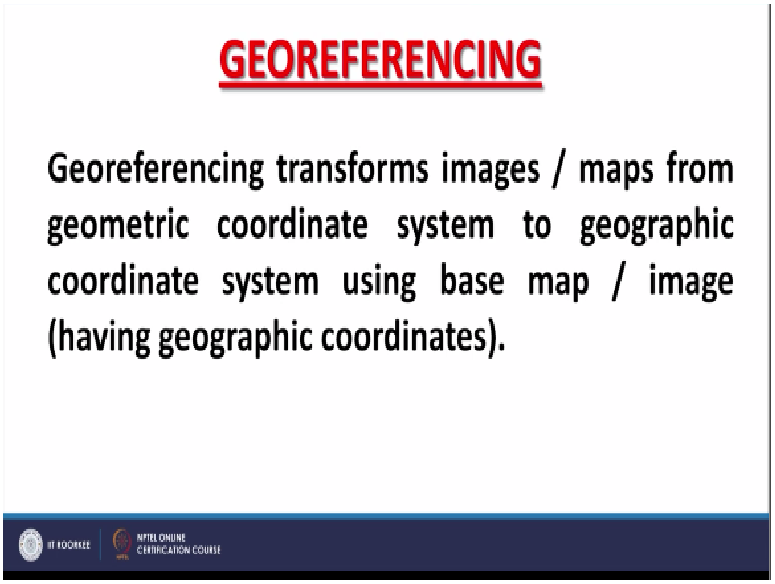

So geo-referencing is you can see in the definiiton is the transforms images or maps, even maps can also be geo-reference. If suppose I scandle survey of India to proceed. Now to proceed might be having inprint form the lattitude longitude mark, but this is an image laster image and it is having origin at the top left corner, that means it is still in the geometric domain.

So now this image, though it says image of a map, so we can call as a map, but there is also no geo-reference. So in order to bring these geographic coordinates and image this technique is required to transform from geometric domain to geographic domain. So the geo-referencing basically transforms images, maps from geometric coordinate system to geographic coordinate system.

And this concept the entire thing as you know in digital image processing and also in the geographic information system it is based on the mathematics which we have going through in our early days is a coordinate geometry. So the concepts are really coming from the coordinate geometry here. And that is why the geometric coordinate system and two geographic coordinate system using these map or having image having geographic coordinates.

You need something standard on which you will transform and so you require may be some base map, may be ground control points which are collected in the field using GPS or differenciate GPS or may be having the master image which is already geo-reference. So as taking that one as a master image and row image which is in the geometric domain can be transformed by collecting the GC PC or ground control points which we will see little later.

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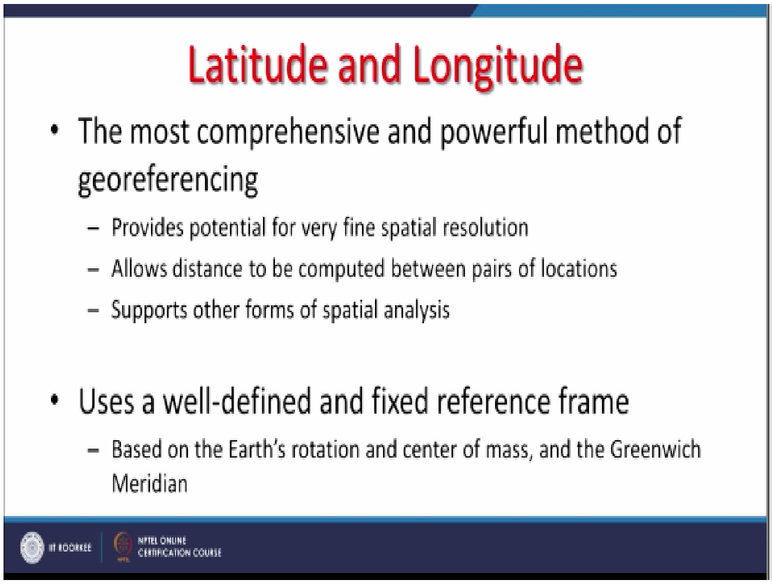

Now before that we also understand very basic things about this lattitude and longitude that the most comprehensive and powerful method of georeferencing in which these are in boards, this provides potential for very fine special resolution. So all kinds of special resolution images can be georeferened there is no, the georeferencing is not dependent on a special resolution, allows distance to be computed between pairs of locations once it is georeferenced.

So you get in real distance in like meters rather than in pixel values. And also supports other forms of special analysis area measurement, length measurement, and angle measurement all becomes very possible and the value will be in the meters or in degrees and so on so forth. And the uses of well defined and fixed reference frame which we use for georeferencing, and which is based on the earth rotation and the center of mass and Greenwich meridian or Greenwich mean time. And because there from where the zero degree longitude passes that is basically our reference line.

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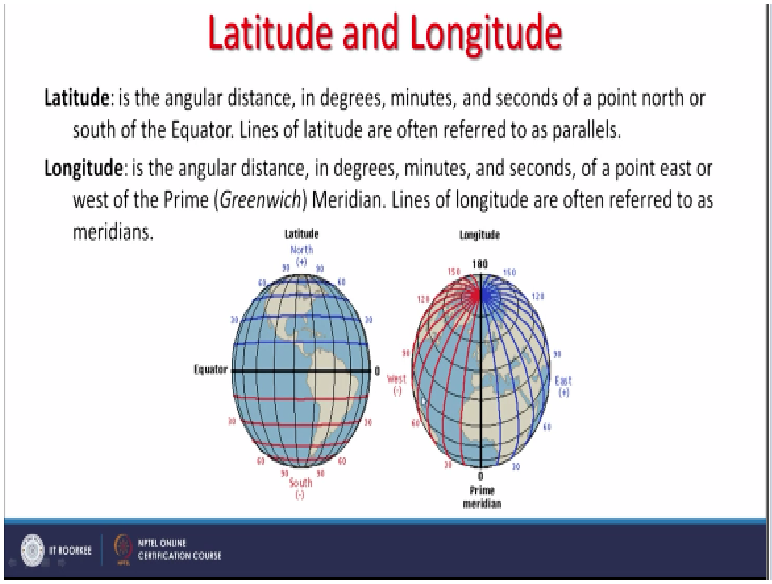

So lattitude that we know, so quickly I will go through we say angular distance, in degrees, minutes, and seconds of a point north or south of the equator. Lines of lattitude are often referred as a parallels. And in case of longitude we say angular distance again, both are angular distance, both are measured in degrees, minutes, and seconds of a point east or west of the prime or that Greenwich meridian and lines of longitude are often referred as meridians.

So here in this figure you can see that the lattitude are shown in the horizontal lines and the equator is in between earth, these are all imaginary lines, except the zero degree longitude which has been marked on this observatory and in Greenwich near and then, so that is the board reference point or we also call prime meridian. So this prime meridian is shown over here and which is zero degree longitude so half of the globe will fall on the east of prime meridian and half of the globe on the west of prime meridian.

Why these are important because in georeferencing this is the basis where two transform geometric domain to geographical domain.

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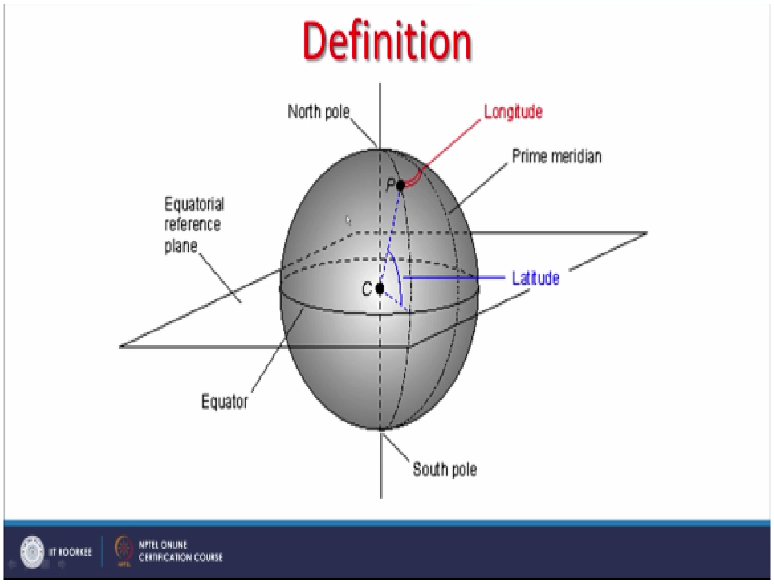

Now as you know that if it is a point is lcoated here then because of this angle we will have lattitude as well and longitude as well, prime meridian is shown here, this is the equatorial axis or plane area is there which is equatorial reference plane and you are having north pole and south pole here. So any point on the globe can be defined using these longitude and lattitude values, because both are values in angles that is why you measure them or put them in degree, minutes, and seconds.

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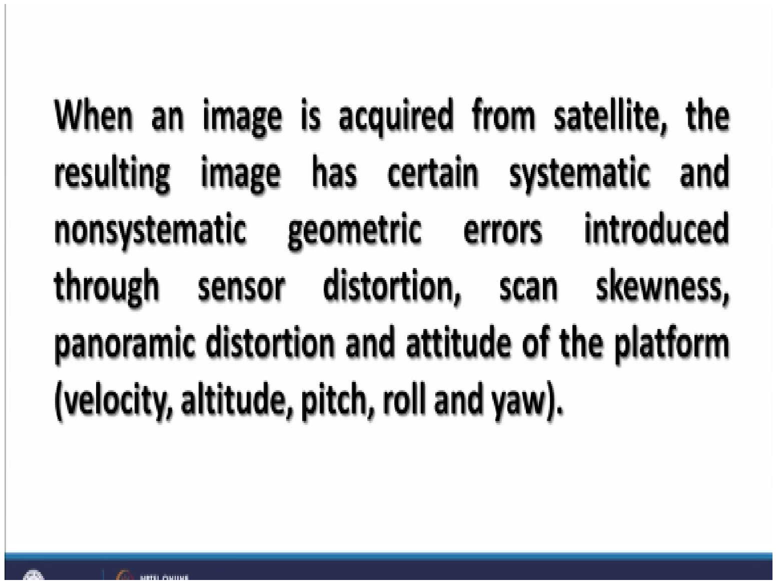

So now as I have mentioned very briefly that when an image is acquired by a sensor on board of a satellite the resulting image may have certain systematic and non systematic geometric errors. One error is already coming, because most of the images which we use in digtal image processing are coming from polar orbiting or near polar orbiting satellites. And due to the earth rotation the shewness effects will always be present in raw images, so that also comes through the sensor distortion, sensors may introduce some distortions.

The scan skewness is always there because of rotation of the earth at the time when data is being acquired, so it is always skewed and panoramic distributions might be there because it is covering and depending on the special resolution it may be covering a large part of that, so earth's curvature also place very major role there to bring distortions in your image and altitude of the platform, because these space crafts are moving in the space.

So there might be sometimes because of some malfunctioning or other things during the data acqusition, there may be change in velocity, there may be change in altitude, that means the height of the satellite is changing, they are moving a pitch or roll or yaw the moments all kinds of these moments can also happen, because these are, they do not have though we say in fixed orbit, what really they are flying, free flyng kind of thing.

So they may have distortions like this pitch, roll and yaw, and all these moments of a sensor will bring me distortions in your image. And our aim is to remove all of these in one go using georeferencing techniques, so that is why it is very, very important.

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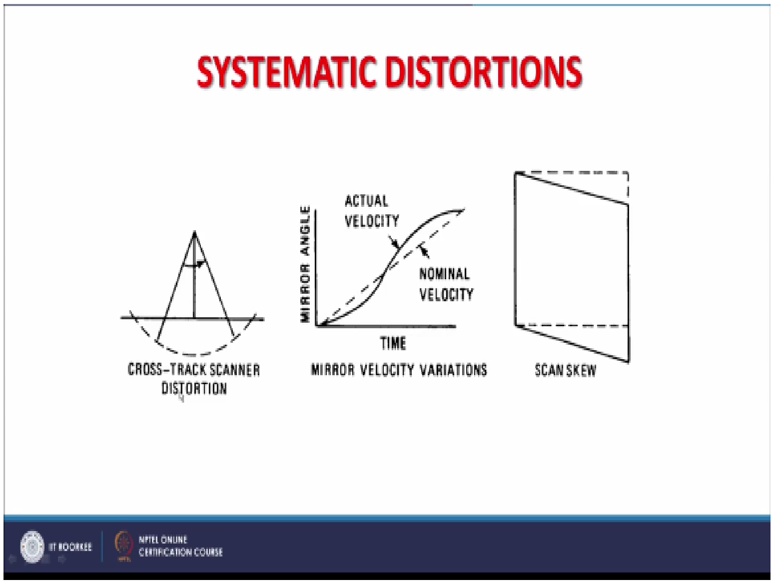

Now some distortions may come from cross-track scanners. We have discussed different types of scanner along track scanner cross-track scanners will bring distortions especially in the images which are relatively having towards resolution. So like land slide dimensions and others had this issue problem. When the scanners which are having the mirrors and press bloom scanners work onto, when they are having the mirror which shade now.

So these are the octo mechanical devices and then therefore, there might be a change in the variation and the velocity and that may bring a change in this. So like here the normal velocity should have been like this, but actual one is like this or you move. The skewness will bring this kind of error in your image so that is distorted because of earth moment when data is being acquired.

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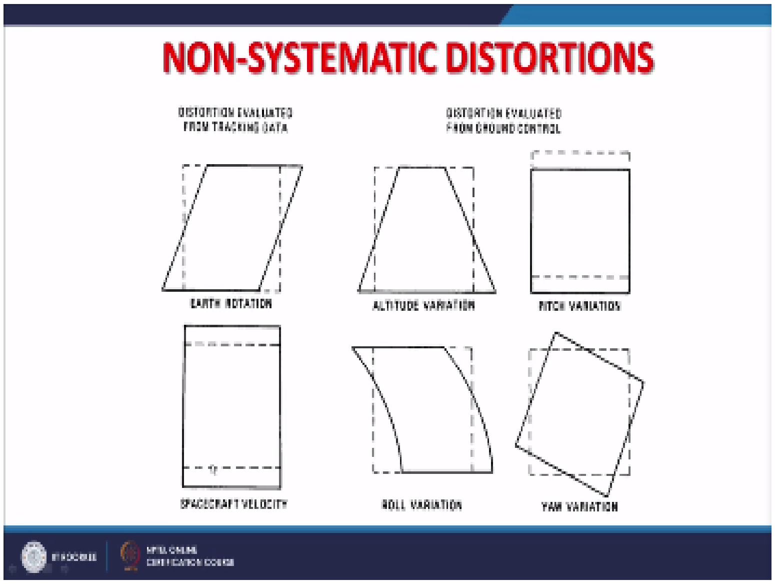

There are some other errors which I have mentioned like earth rotation, error skew that is distortions coming from tracking data that is earth rotation due to earth rotation at the time of data acquisition especially in case of polar rotating satellites, altitude variation when suddenly there is a change in the altitude of the space craft, you may have variations something like this, you may have a pitch variation that suddenly dips towards the direction in which it is going or in the opposite direction.

So that may bring the pitch variation the space craft velocity variation may be in very different kind of representation of the image, roll variation the space craft is going and it rolls something like this. And it tilts on the sides, so that we call as roll variation and another type of variation which can be introduced or distortion in the image of the yaw variation. So this yaw variation can also happen and it is not that only one distortions will be there, there might be multiple distortions in a single image might b e present. So many of such distortion can be removed by implying and georeferencing technique.

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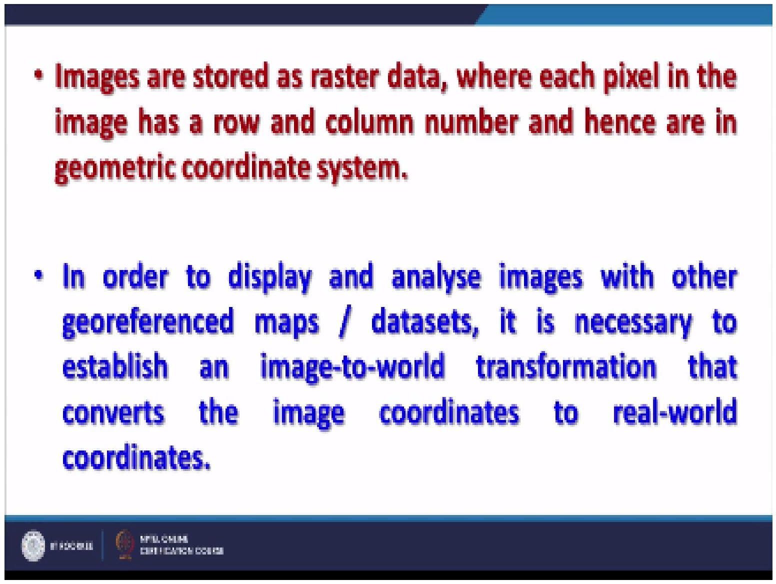

So images as you know are stored as raster with two dimensional grid, each shell is represented in pixel value which maybe a reflective or limited value. And then E in this image they are stored in row image as rows and column numbers and hence are in geometric coordinate system. Our view is to bring geographic coordinates with the image. So in order to display and analyze images with other georeference maps data sets we want to state many, many images together of the same area may be image and map and some other like control lines or some other features of geological map or soil map.

Then how we would achieve if you are having a georeference maps, everything is georeference, then you can state one over other. So it is necessary to establish an image toward transformation, the purpose here is to transform from geometric domain to geographic domain that converts the image coordinates to the real world coordinates.

And real world coordinates are in terms of, maybe in terms of latitude, longitude depending on which projection if you are using, if you are using digutium inversely transverse marketed projection, then these might be in your meters, or in easting and northing and depending on the different projection. But these all will be in a geographical domain rather than in geometric domain.

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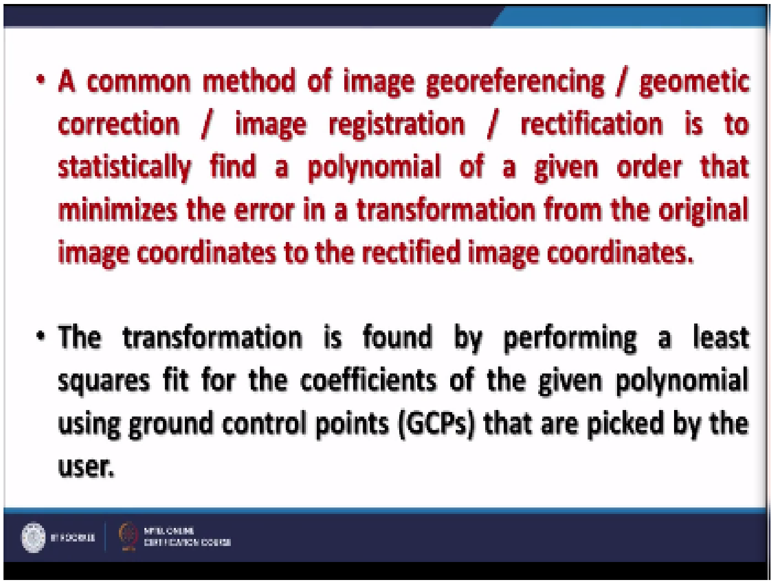

So this is a common method, important method which is also called geo image georeferencing which we are using also somewhere in the literature you will find geometric correction, image registration or image rectification. So many terms are used for the same processing and is a statistical what exactly we will do, so it is a statistical find a polynomial of a given order, we will decide depending on the distortion which are present in image, which polynomial order will be used.

Polynomial equations we have studied in our school days, these are now being going to be used and of a given order depending on the distortion that minimizes the errors in a transformation from the original image coordinates to rectified image coordinates. So it is because not only it has to be transformed, but it has to fit in the new system that is the geographic coordinate system. So this transformation is found by performing a least squares fit for the coefficient of a given polynomial using ground control points or instead we call a GCPs that are picked by the user.

And we decide that which is going to be the GCP, so what basically GCP is a ground control point, but the meaning here is basically that these points are common are present in my master image or master map as well as in the row image. For example, there may be two road crossings or may be a bridge over road or may be a bridge over the railway line, these are the fixed point, then moving point, there are the bonding river in a plane area cannot be the GCP.

Because in few years time that we move, so the age or the date on that master image was acquired or map was made ended image which is not georeference, we have a different dates and therefore, such objects which are moving in correct or in nature cannot be used. So that we have to select very carefully the GCPs which are fixed and the example I have given, the bridge, crossings, may be a quarter and so on. So these can become our reliable in GCPs, because GCPs place very important role during the image rectification process.

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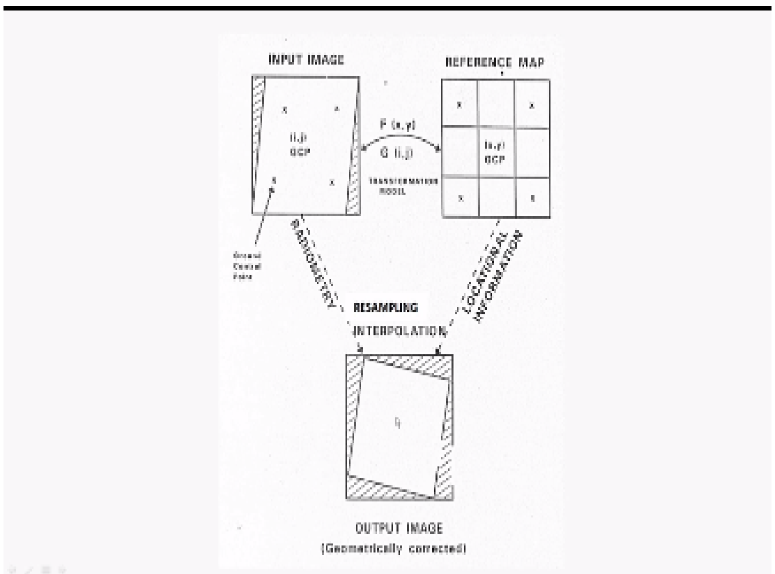

Here is a very schematic example is of georeferencing is shown in a very simple fashion, that this is my row image or input image which is not yet georeference. So it belongs to a geometric domain, control points, four control points are shown. The corresponding control points in my master image or a map are also shown here, which is in geographic domain. Now what basically I have to find the polynomial equation and the coefficient will allow me to shift pixel by pixel from this image, input image and to the master grade which is georeference one.

And by doing a third step here by this re-sampling sometimes you may find people use where interpolation but interpolation is not appropriate term here re-sampling is more appropriate term and ultimately you reach to this. So there are three steps major steps in geo-referencing, first tagging or controlling through ground control points the time you're the image the raw image with master image or master map using these ground control points.

The second one is finding the transformation coefficient where each pixel will be transformed into new geographic domain and third one is what is going to be the value of pixel which will be transferred, because it is not all the time there are out of three major re-sampling techniques the first one will transfer the original pixel value, but the other two will not transfer so what should be the pixel value how would be decided that is will all will considered under the re-sampling.

So there are three steps first is the tying up that is the using control points, second one is transform finding the transformation function of a given order which we will decide depending on the distortion which are present in the image and third is the what is going to be the pixel value that is through re-sampling. Now, how to decide about the polynomial equation or given order.

So what order I will choose, if it is a simple transformation from geometric domain to geographic domain that there is no other leathered means there is no rotation, no change in scale or no wrapping is required it is a simple transformation from one domain to another then we call as a first order polynomial.

And also in literature you may find a conformal transformation function, when your image requires not only transformation from geometric domain to geographic domain one it also requires change in scale and also rotation of the image, the we will go for second order polynomial.

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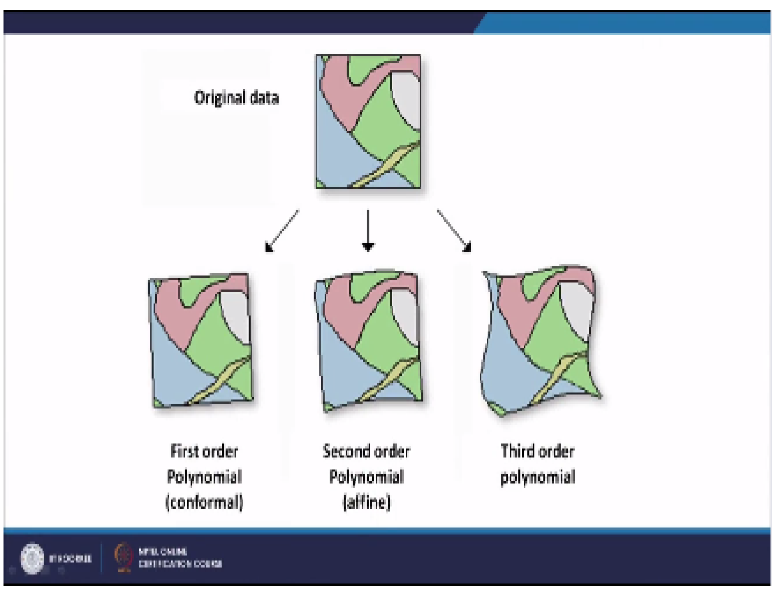

Or it is also call a fine transformation, third order polynomial is that when all these things which I have covered in second order that means transformation from geometric to geographic one rotation of the image change of a scale plus wrapping, and this requires in case of relatively low spatial resolution data which are representing a curve part of the earth and if you want the flatten because the geo-reference image will always represent the earth even if recover part of the earth in a flat form.

So that is why then in such cases you would go for third order polynomial, there are in software's you may find they have implemented up to 12th order but generally beyond third order is not required because then all kind of distortions. Then we will be handle by the third order polynomial transformation. So why to go for higher order because once we go for higher orders then the number of GCPs require.

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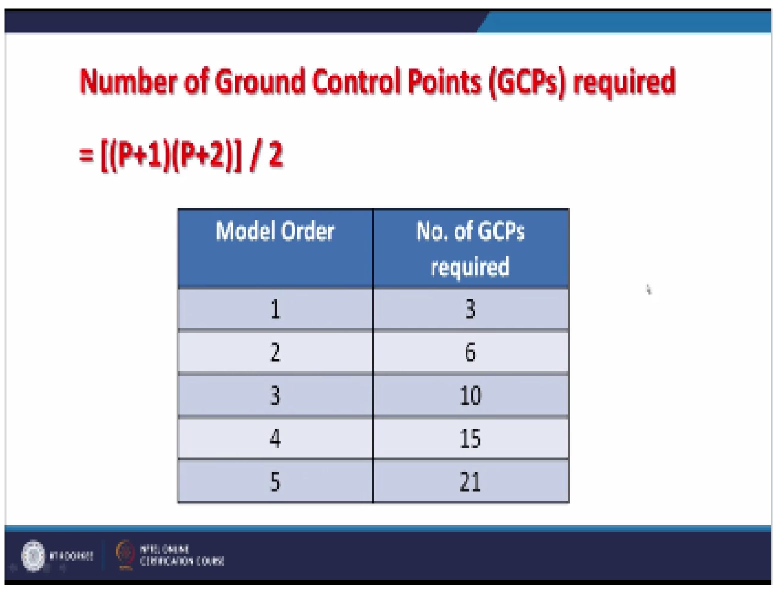

Will increase you know tremendously so there has to be also kept in mind and collecting GCPs is not a very easy task because finding a reliable GCPs is very, very important how the ground control points number of ground control point depending on the polynomial order will be required there is decided by very this simple equation. That P + 1 x P + 2 / 2 and that means that if I go for just first order polynomial transformation then I require minimum number of GCPs are three.

If I go for second order then I require six and if I go for third order then I require ten, now one thing one has to remember vary these are the number of minimum GCPs is which are required without these numbers you will not have that option to go for transformation so these are the minimum but in practice one should go by multiplying by 2. So if you are going for third order polynomial then one should collect at least 30 ground control points.

Some points ground control points which may be giving errors, a large errors may be dropped then denary collected and this by like this through this iteration process one can improve the zero francing the our aim to achieve within pixel zero francing that means that of course pixel is a unit so it is individual so beyond that we cannot perform. But our aim is that the error which we will get through this polynomial transformation coefficient calculation that should be within the dimension of a pixel. It will depend on the restitution, higher resolution you will have a very small value to manage and a to achieve whereas lower special resolution then larger values can be accepted.

So this is very important that the though a minimum number of required depending on polynomial order are very small but in practice multiply by 2 would give you much better results.

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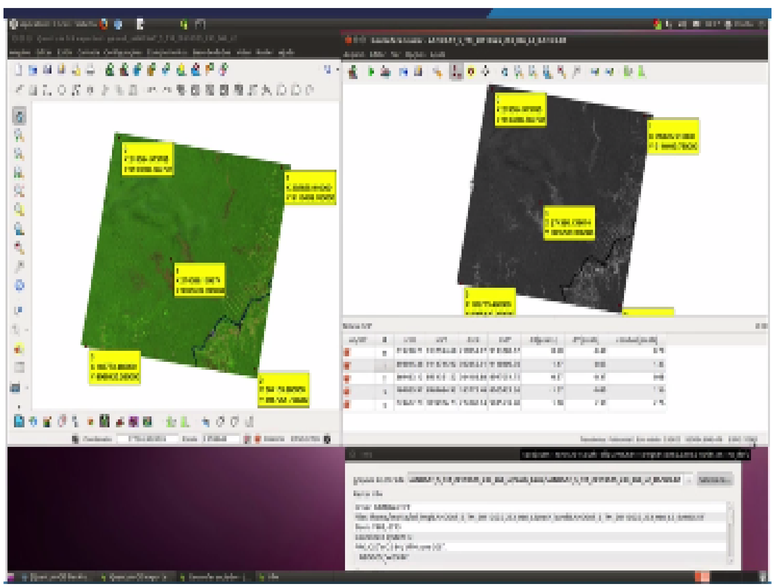

So now like for example suppose here five ground control points have been selected and these have been chosen in this example and the corresponding point of a master image are also chosen.

And this will give you that how much you know the differences are there because this is in geometric domain this is in geographic domain.

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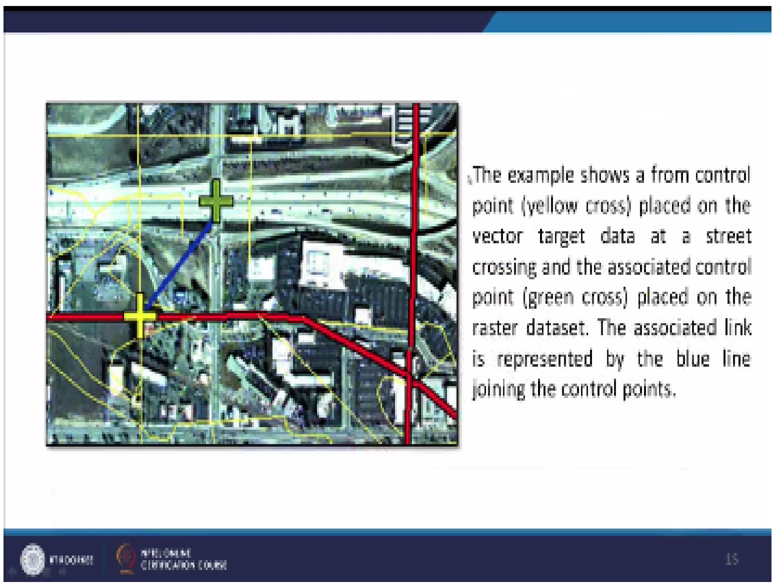

Now if error is large you may had a situation something like this the points suppose to be here the green plus sign but whereas point is displaying here. I have chosen across but it is showing that if I go for next step then this point is going to be the location which is yellow one. So the examples shows from a control point yellow cross placed on the vector target data that is street crossing which is this one.

And that end the associated control point that is the green cross placed on the data raster data. And the associated link this blue line is represented by the blue line joining the control point, so this should not be very large. This is always displayed if we join it little bit we will able to see it what is the length, so this length should be very less in order to achieve a high geo referencing.

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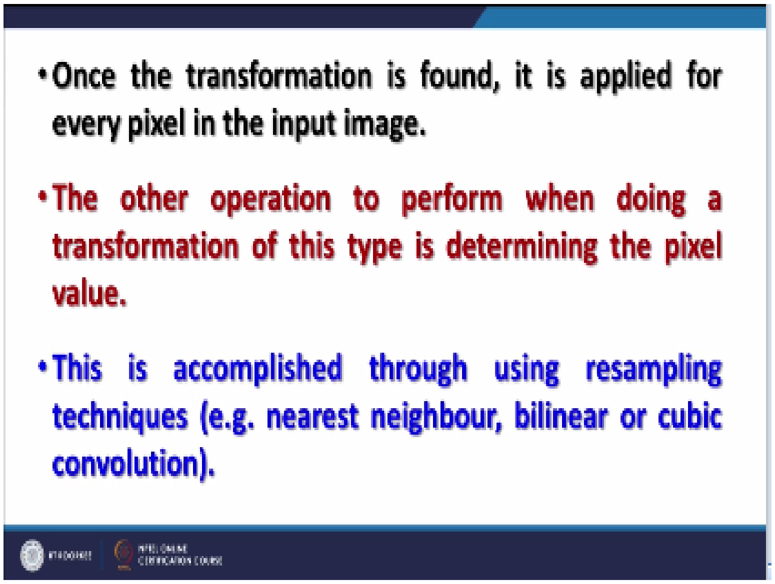

Once the transformation is found it is a applied for every pixel in the input image, and the other operations to perform and doing a transformation of this type is to determining the pixel value that is the third step that is the re sampling. Different types of re samplings are there which we will see dairy later and this is accomplished through using re sampling techniques that is nearest neighbor by linear and cubic convolution.

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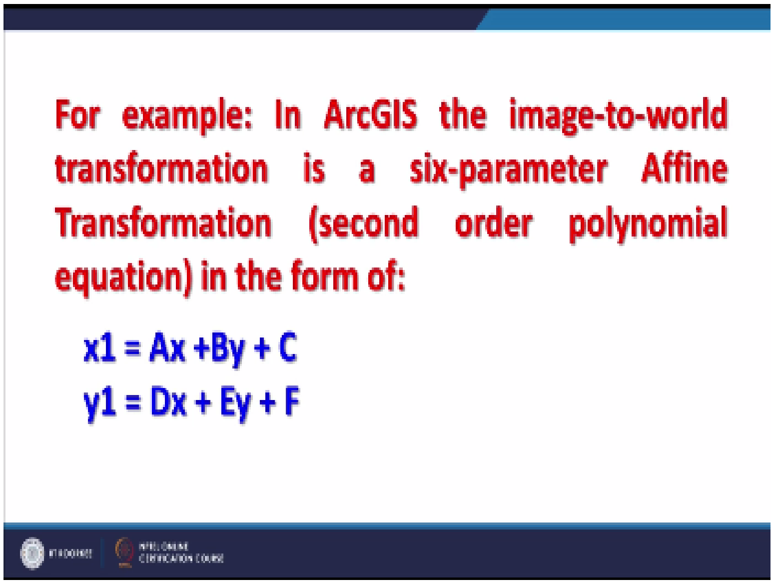

The detail we will see little later soothe transformation can be represented by a polynomial order M such as this is a general equation for given polynomial order we can depending on the requirement as mention earlier that if I am using a relatively low special resolution image then it will be also represent in the curve part of that. So therefore the third order polynomial is most suited but FA it is having a relatively low special resolution data then second order polynomial can also be chosen.

Like a example in am taking from a very popular GIS software may be the same in a dass image processing software that in ArcGIS the image toward transformation is a six parameter a fine transformation that is the second order polynomial equation in the form of x1 ax + b/ + c / 1 = dx e/ nf, the mean n is I have been mentioning that from row image each pixel has to be transformed where it will go this is decided by this equations.

X and y ahs to be decided initially x y is are a row number and column number later on this x y becomes geographic coordinates. So where this pixel will go that has to be decided through this equations. Now here this is the image spaces is giving here this is my raw image also.

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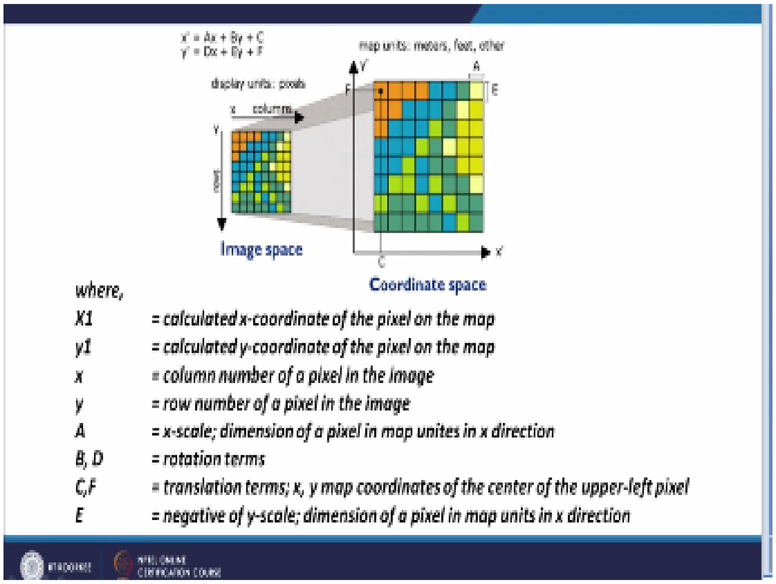

And this is the image which is having geographic coordinates so that is transform a pixel Y pixel from here to her using that is again that is second order polynomial function. Here where this X1 or X' should have the calculated x coordinate of the pixel on the map and wide as is the calculated by coordinate of the pixel on the map, and the x is the x which is after this a is the column number of a pixel in the image and y is the row number of the image which is the row image.

Now what we are trying to achieve x and y of for the new image which will be the geo reference image and now there is a is the scale dimension of the map units and direct action because now in second order polynomial equation not only is a simple transformation form geometric domain to geographic domain but we are also going to change a scale and rotate the images well, so that is why scale change will be control or handle by this A and B and D are the rotation terms which will be use to rotate your image because a raw image may have the skewers effect or a distortion due to other inputs has we have discuss earlier.

These all will play very important role and the C and F parameters which are coming in this second order polynomials are the translation terms x/ s coordinates of the center of upper left pixel. Because raw image the coordinates be always consider from top left corner and then the last one is the E, which is the negative of y scale dimension of pixel or mapping units in next direction.

This is now again as I have mentioning that in the raw image the X Y are always counted from top left corner whereas in the geo reference image they are counted from the bottom left. So this negative in the Y scale has to be incorporated. Now as I have just mentioned that y scale that is the E is negative.

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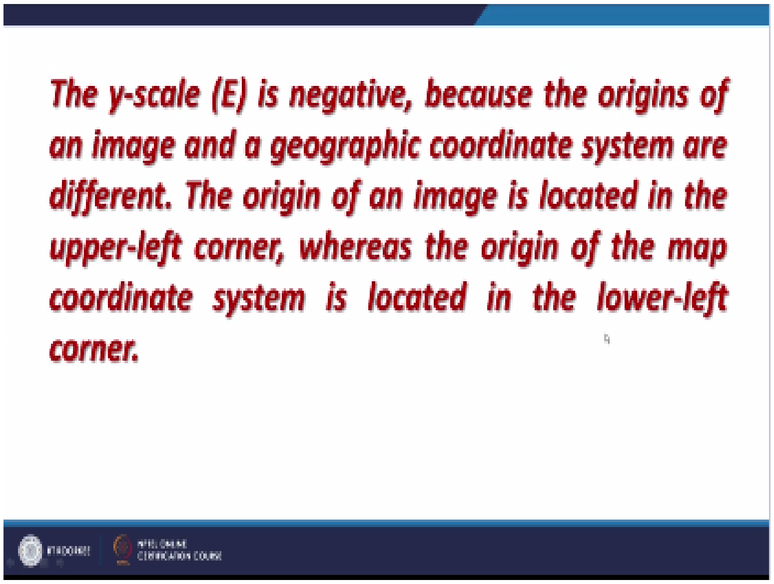

Because the origins of an image and a geographic coordinate system are different and the origin of image is locate in the upper left corner whereas the original of the map coordinate system is located on the lower left corner.

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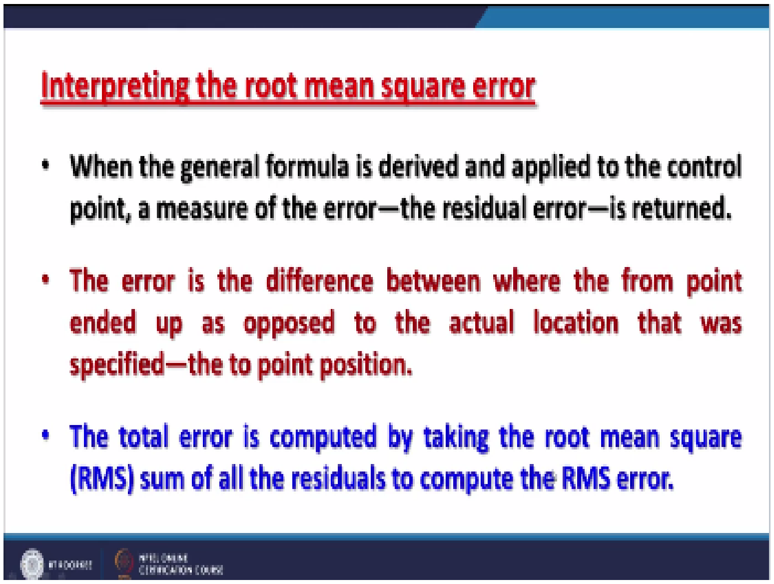

Now once we go for this then we get this $\sqrt{Pv^2}$ error because of this GCP is which be tie up with the raw image and a master image so when the general formula is derived then we use this polynomial order has been decided then the applied to the control points a measure of the error the residual error is written. And the error is the difference between where the from the point ended up as earlier I shown the example the blue line larger the blue line more the error, smaller the blue line depending the color I am just giving the example the color may be depending on different software's.

Ended this lien should not be that the line between where from the point ended up as suppose to the actual location that was specified to the point position. So this should be minimum as for as possible if a heavy ground control point is giving a large RMS error the it should be deleted and maybe recollected may be a different location a GCPs may be collected and by which we can reduce the overall √ mean square of our registration process.

So the total error is computed by taking the root means square some of all the residual to compute the RMS error, so there will decide whether we are falling within one pixel by when we finally go for final step there is re sampling or not. So this is important to see that we achieve within one pixel s the dimensions or the special resolution of the image. This value describes how consistent the transformation is between the different control points or the links like blue line.

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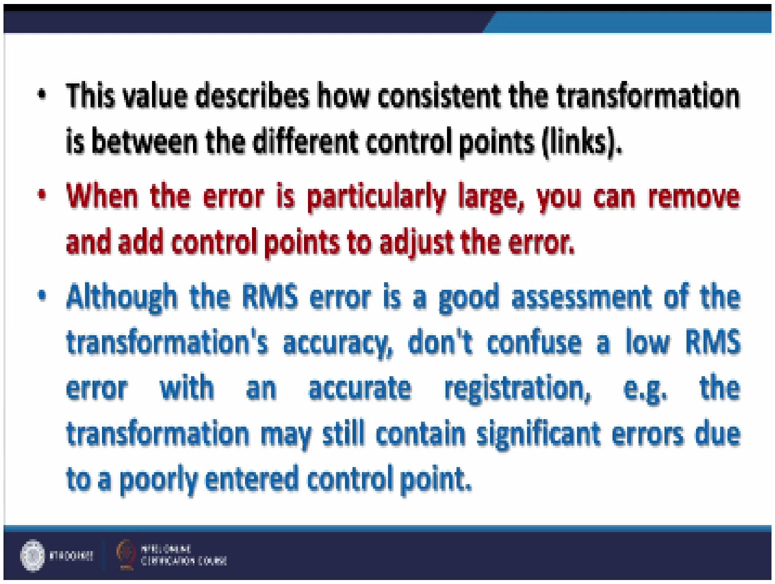

And when the error is particularly large you can remove and add control points to adjust the error which I have mention although the RMS error is good assessment of the transformation accuracy do not confuse a low RMS error with an accurate registration, for example the transformation may still contain significant errors due to poorly entered control points. If control points are unreliable though this RMS is low that does not mean that you will achieve a good zero fanciers.

So one has to be very careful while collecting GCPs, GCPs have to be very, very reliable, reliable means here the GCP which I am seeing in raw image so the same GCP corresponding GCP I should be see on my master images well both should represent of the same edge and same location then I will achieve a very good geo differencing.

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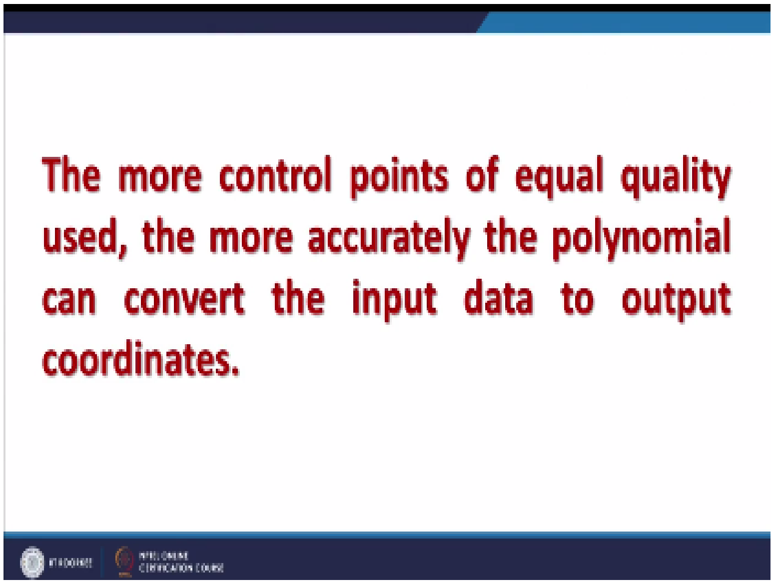

And the mode control points of equal quality used the more accurately the polynomial can convert the input data to output one. I have mention the minimum say may be require 10 4th second third order polynomial but it would be better to collect 30 or 20 so that day you will achieve more points will allow you to drop few points, so if you have collected 30 instead of 20 though you are suppose to collect only ten the minimum one that at least you are having monarity to draw few points and still you will achieve a good geo references.

So it is always in good practice to multiply either two or three to achieve good, now the third step or the final step in geo differencing is the re sampling method and here in this schematic.

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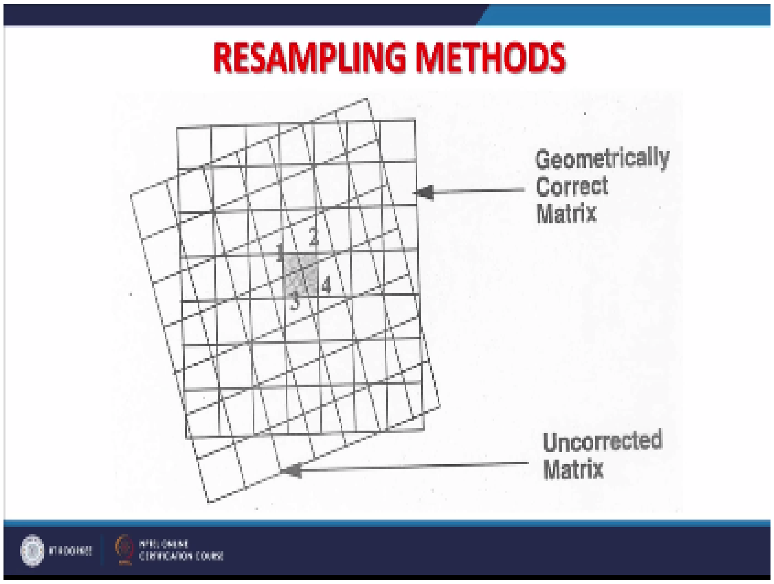

When the master image is in the background and this rotated one is the raw image which is shown here in the form of matrix it is shown but basically y matrix because we are handing raster data this has two dimensional matrix. Now here the target is this one which is the settled one if you see the over lapping here that the pixel one pixel two pixel three and pixel four these are the just you know idea of pixel not the real pixel value here I am talking.

So if so what in the first technique that is re sampling technique which is the nearest stabber what would be done that first search would be made over this overlapping image is master over and this raw image and then will decided that which pixel of raw image is having the large coverage over the master image. So in this particular example the pixel three is occupying the maximum area of your target pixel.

And that means in nearest reverie sampling whatever the value pixel 3 is having say it is having 105 so that target pixel will also have 105, so the pixel which is having the maximum overlap that value will be decided or transform to the target pixel. But if we want to more 1 2 3 4 because they two are overlapping to different proportions, then if we go for weighted average that the one which is having the maximum over level will carry more weight is by deciding the pixel value of the target pixel then weighted average will be taken and all four pixel values will involve in calculation.

Depending on their overlap they will carry accordingly the weight age and that a new pixel value will be decided based on weighted average and this technique is call by linear. Four pixels are involved but if we go for smoother image then instead of four pixels we can go for 4/4 that means 16 pixels and it can involve now distance to that target pixel. So the distance can be assign a weight and accordingly the values can be calculated and this kind of calculation of in during re sampling is called accurate convolution. So quickly we will see that the nearest neighbor re sampling.

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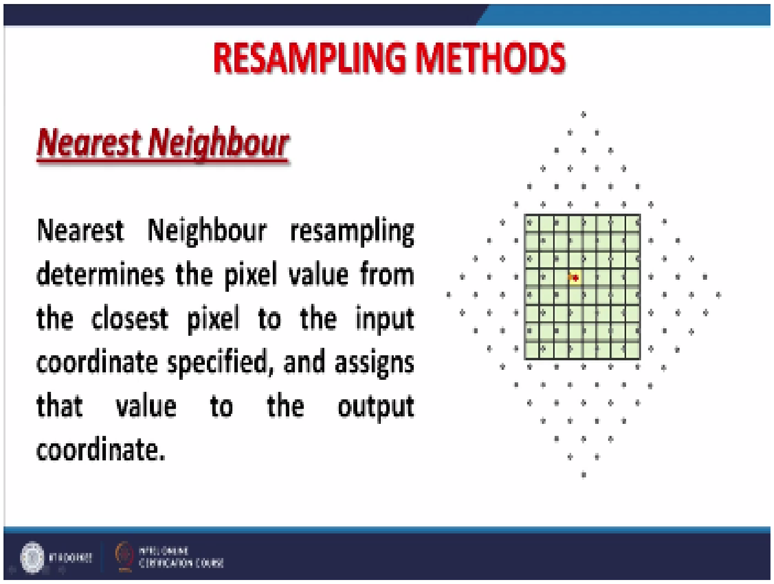

Determines the pixel value from the closes pixel to the input coordinate specified and assign that value to the output values, so the one which is overlapping maximum that value carry in the target pixel,.

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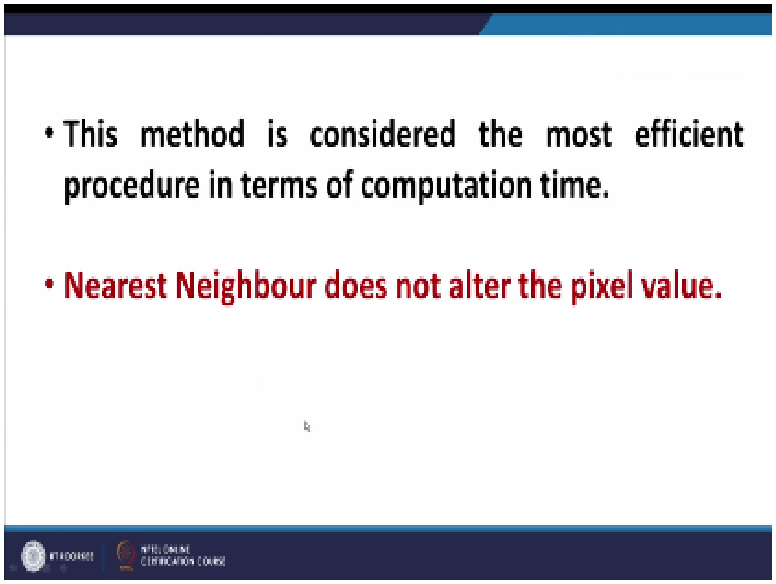

This meth considered the most efficient procedure because there is no alteration of the pixel value original pixel values are entered, many times we choose this nearest neighbor because later on we maybe that is geo references image for image classification. And therefore we do not want to lose the image quality we do not want to alter the image or pixel values and therefore this method in that way is very good and efficient it does not take much time to achieve this kind of re sampling. Divide not much calculation is required so nearest neighbor does not alter the pixel value.

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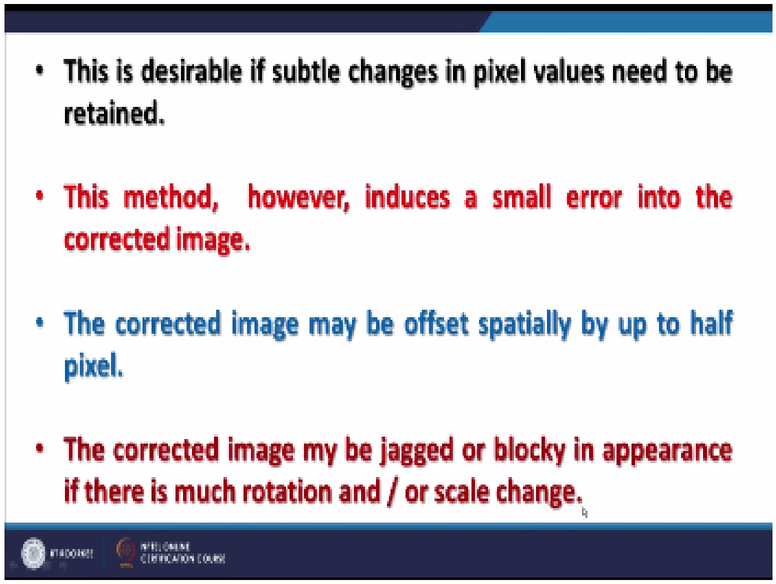

And this is desirable if subtle changes of image values between a need to be retained, that has I have said in case of classification or some other we do not want to lose the image quality we do not want to depurate the image and therefore the nearest neighbor is the best suited in such cases and this method however induces a small error into corrected image. The error maybe the offset spatially by up to the half pixel because we are choosing only one pixel value so there might be a little error.

Uncorrected image may be jagged or blocky in appearance and if there is much rotation or a scale change.

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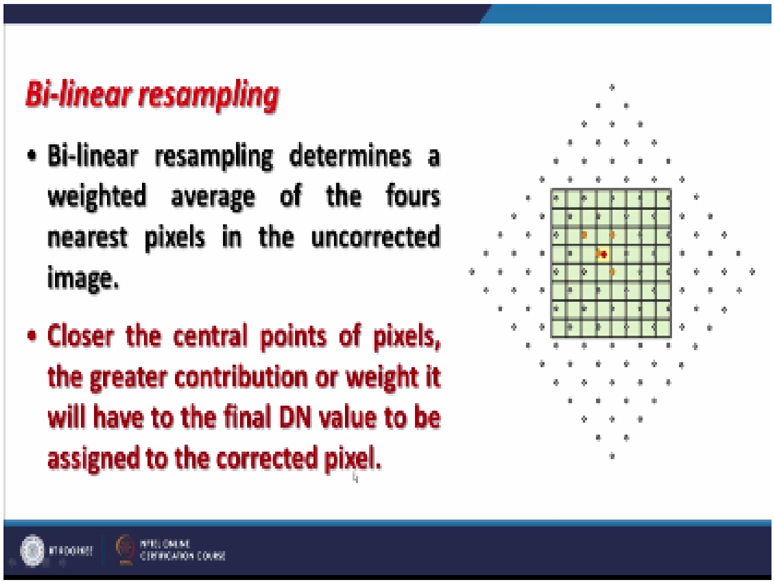

In case of bi- linear now 4 pixels are involved bi linear re sampling determines a weighted average of the fours nearest pixels in the uncorrected image. And the closer the center point of the pixel the greater contribution or weight it will have to the final DN of pixel value to be assign to the corrected. So as I mentioned earlier that the pixel of raw image which is overlapping the maximum will carry the maximum weight is while deciding the pixel value for target pixel. Now bi- linear re sampling generates a smooth appearing re sample.

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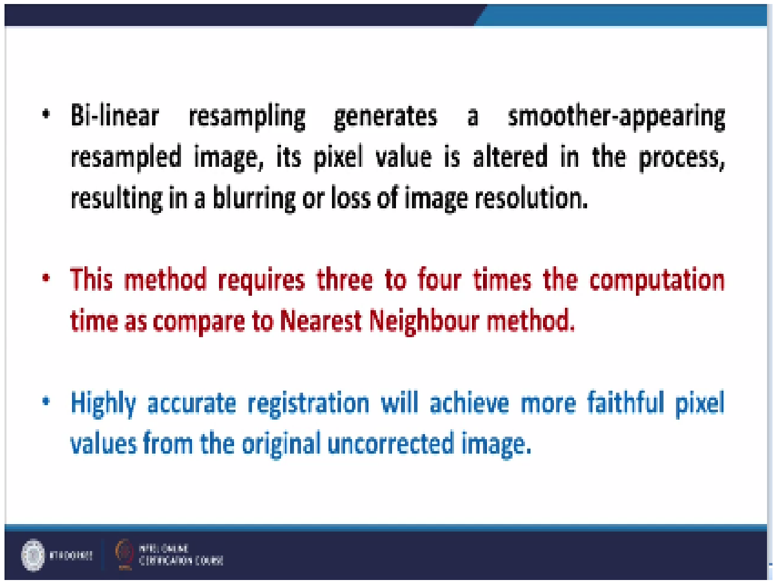

Because here now pixel values are being altered the pixel values are altered in this process resulting in a blurring or lose of image resolution. So if you do one to compromise on the image quality then do not chose bi- linear then nearest neighbor in that way is very known as kind of re sampling technique. This method require 3 to 4 times the computation time as compare to nearest neighbor because 4 pixels are involve they are weighted average has to be calculated in case of nearest neighbor not much calculation just transformation from original to target one.

And highly accurate registration will achieve more faithful pixel values if I have done the first two steps very accurately from the original uncorrected image and the last one here is the cubic convolution.

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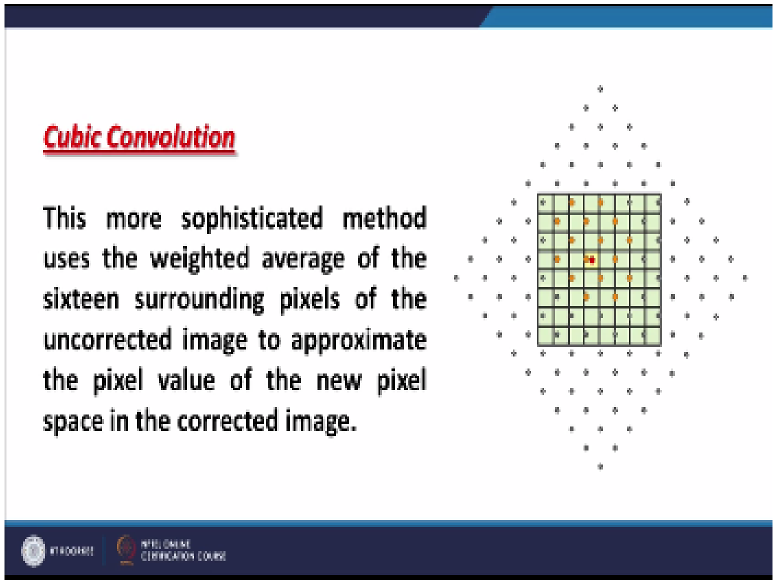

This is more sophisticated method which uses weighted average of the 16 surrounding pixels of uncorrected image to approximate the value or estimate the pixel value of the new pixel space in the corrected image. So now 16 are involved therefore it is not the deficient as nearest neighbor or bi- linear and it is the it is closer to the perfect sin x / x.

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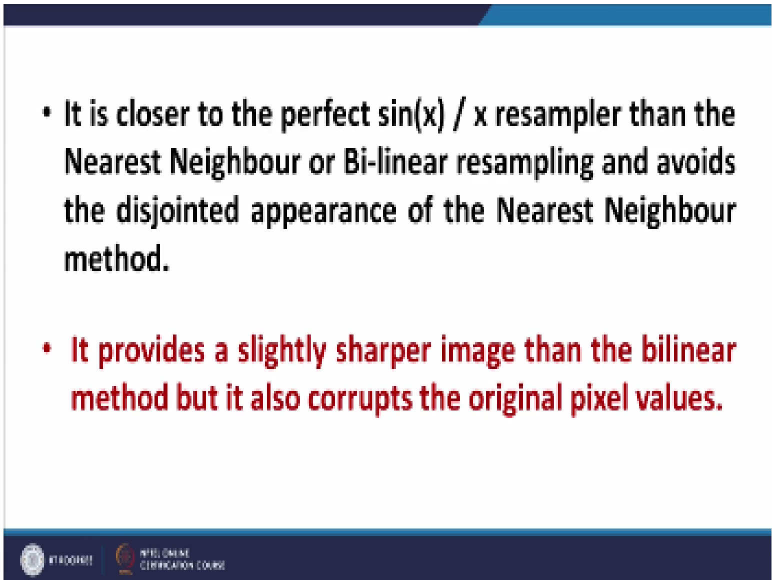

Then the nearest neighbor or bi linear sampling and avoids the disjointed appearance of the nearest neighbor method because they are half pixel problem which mean may absorbing case of nearest neighbor re sampling will evaporate completely here because 16 pixels average weighted average has been counted here and it provides a slightly sharper image than the bi linear method but it also corrupts the original pixel values and use it alter the pixel value and this method is not recommended.

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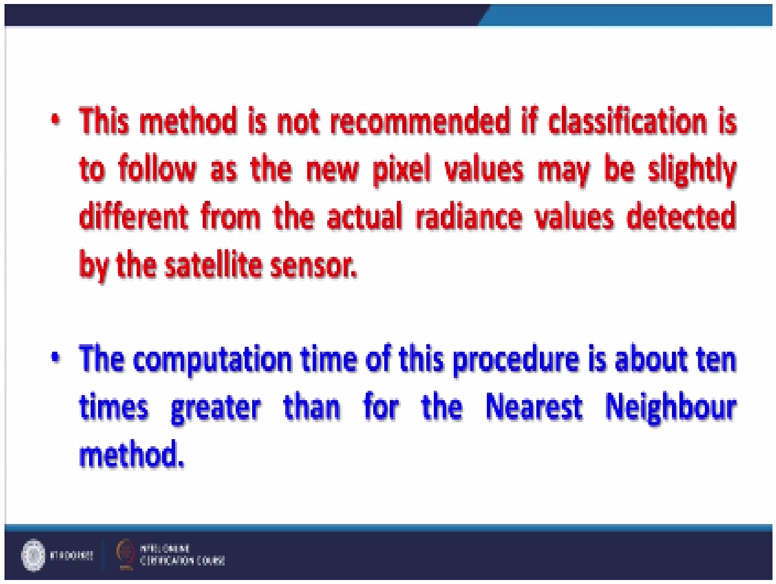

If classification is I have already mentioned is to follow as the new pixel values maybe slightly different from the actual radiance values detected by the satellite sensor. So there are always trade of you achieve a very good re sampling G referencing after even cubic convolution but the same time you are altering the pixel value, so if in your application you do not accept the alteration or duration of the quality of image then do not go for bi linear or cubic convolution in that case nearest neighbor is much better.

But if you are you want the very high quality of geo referencing you in this process a values are altered it is not a problem for you then you may go for cubic convolution. Yes obviously the computation time of this procedure is about ten to 16 times greater than for the nearest neighbor method because 16 pixels are involved there weighted average will be calculated. And this brings to the end of geo referencing technique. Thank you very much.

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