Introduction to Geographic information Systems

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Lecture - 10
Geo-referencing

Hello everyone, earlier we have discussed about the Preprocessing Operations, which we performed in GIS. Among the preprocessing profit processes we have seen that geo referencing is the one of the very important one. So, in this particular lecture we will be going through details about.

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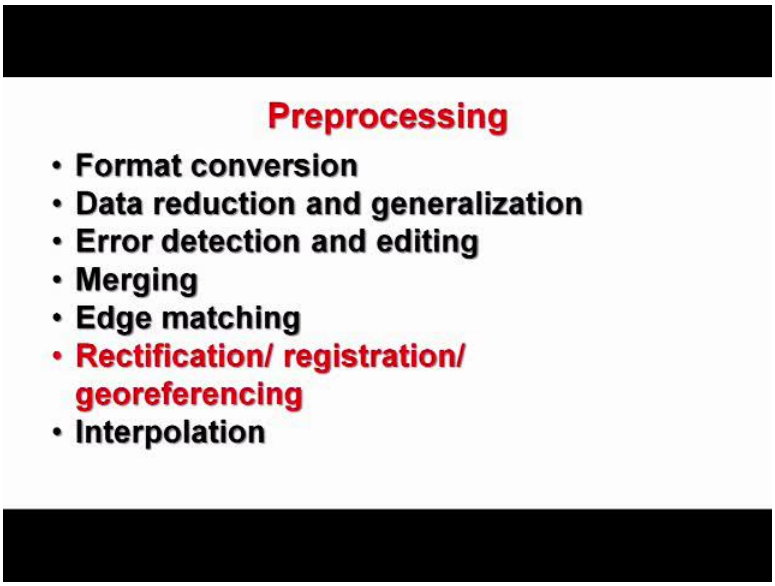

What is basically geo referencing sometimes it is also called rectification also in some literature people will use for registration. So, all these things which we will see in details, why it is required and how it can done, what are the different techniques are available and their comparisons as well? Let us move towards to the geo referencing. Geo referencing basically you understand like this that transforming your spatial data, maybe satellite maybe vector data from geometric domain to a geographic domain. That means, say if I take the example of satellite images, when the data is collected by the satellite it is not in geographic domain. To sometimes orbital data can be used and these images can be geo reference, but that is very crude kind of geo referencing. As we are moving towards higher and higher spatial resolution satellite images, we need to do sort of

manual geo referencing and that too should be very highly accurate, because when we use such data along with other data set in GIS then this mismatching should not occurs. So, therefore, geo referencing is very much required as mentioned that converting or transforming one from one domain which is the geometric domain to geographic domain and this is what is basically geo referencing, as we can see in the definition also.

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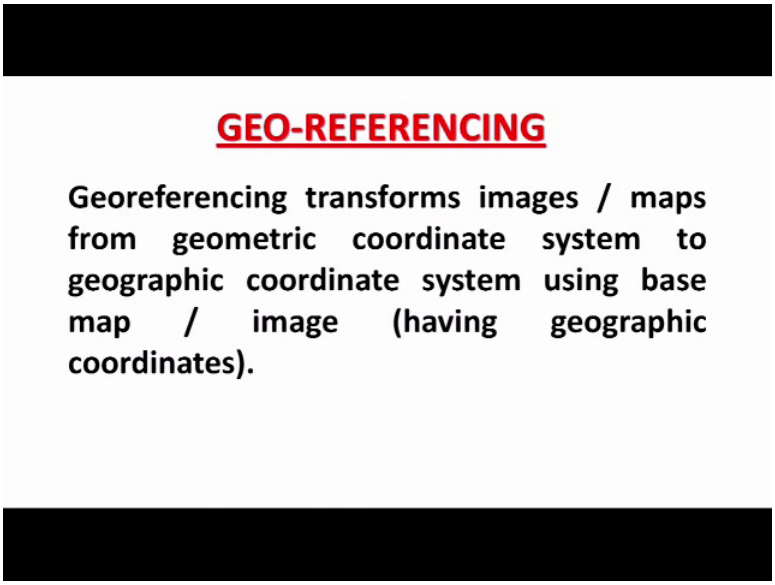

That geo referencing transforms image or maps from geometric coordinate system to geographic coordinate system. Using a base map image having geographic coordinates, now input in this one of course, the raw image is required you might be having for referencing a master image which is already geo reference or master map which is also in a geographic coordinate systems, you can utilize that one. Nowadays very high spatial resolution satellite images sometimes, we have to go in field use the gps collect the ground control points or in short we call them GCPS and using these GCPS we can geo reference.

There is another way of doing a geo reference or collecting GCPS that is in some countries they already having libraries of few thousands of GCPS. So, if those libraries are accessible to us, we can also geo reference using those GCPS which have already been collected which are highly accurate using might have been collected using different GPS techniques, and the third one and the most important way of bringing GCPS nowadays is using Google Earth. Because Google Earth is already geo reference you can

identify the ground control points there and the same grounds control point you can identify in your map or image and can use it. There is various way of bringing GCPS we will see in detail about.

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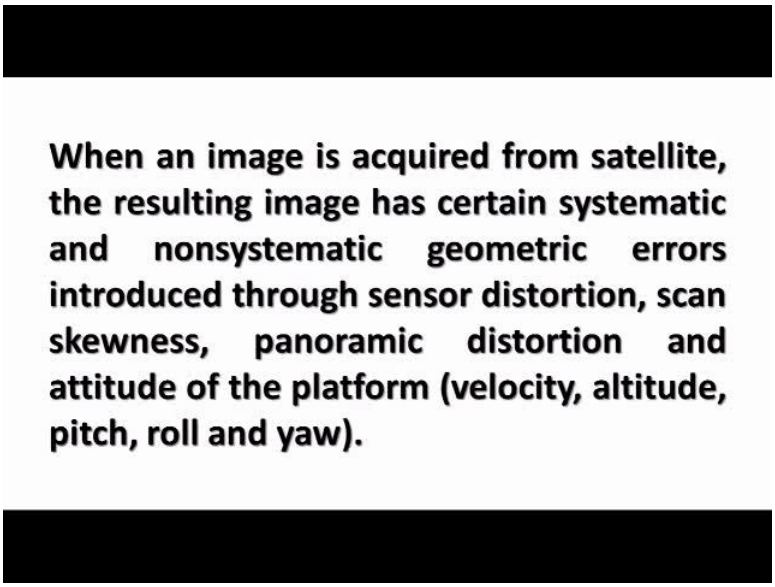

So, when an image is acquired or map is acquired image is acquired from satellite or map is acquired from elsewhere may not be in the system which is may be in the geometric domain may not be in geometric domain and we need to convert from that domain to geographic domain, plus sometimes when data is acquired from satellite then these platforms are moving at a high speed and therefore, they might bring certain errors in the satellite images, the errors might be due to change in the velocity change in the attitude may be pitch roll and other functions are there. So, in earlier versions when we had a mirror scanners still that data we use like landsat MSS data because for chin detection studies we always try go as older data we can access. So, those data sets were acquired.

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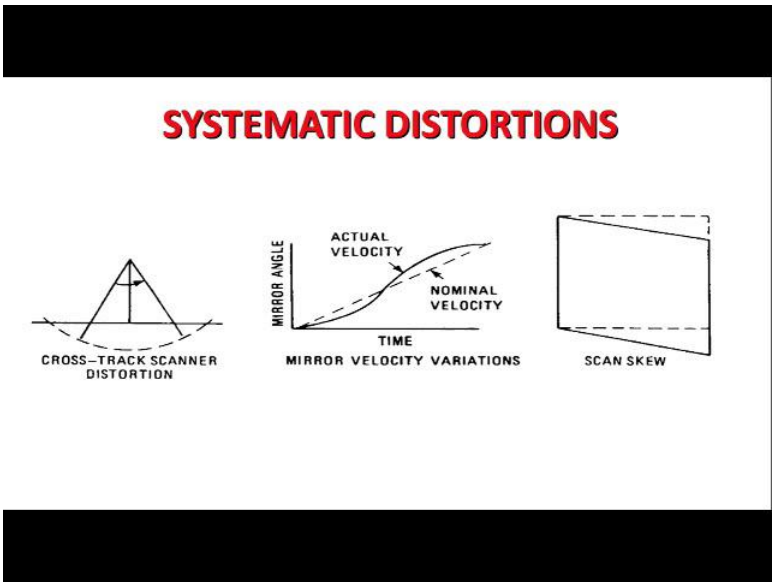

When sensors hit the mirrors, mirrors used to create velocity variations because these are all mechanical devices.

So, therefore, we had some problems because of mirror and skewness is scan skew is to be there and plus in skewness in modern days satellite images also occurs because of the rotation of the earth, during a scene is acquired by the satellite by that time earth rotate and it is skewness may also occurs as you can see that the intended area should have been covered this one, but the actual area has been covered like this. So, we have to correct this one also these all this correction put under the geo referencing category.

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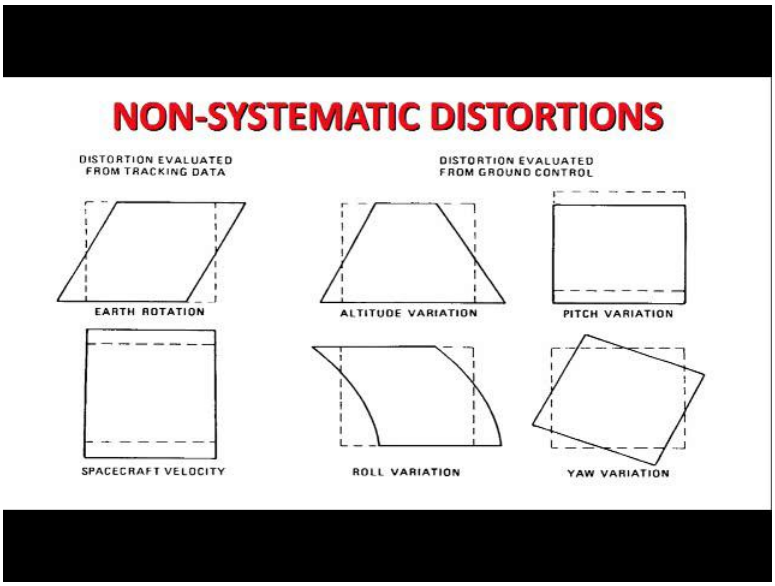

If there is a change in the earth it is rotation this is how the skewness will come, if there is a sudden change in the height of the space craft then this kind of distortions may be introduced in your satellite image then similarly if this pitch variation is there spacecraft velocity changes or spacecraft roll it like this or there is yaw moment like this, then similar problems may arise all these problems in one go can we resolve using geo referencing.

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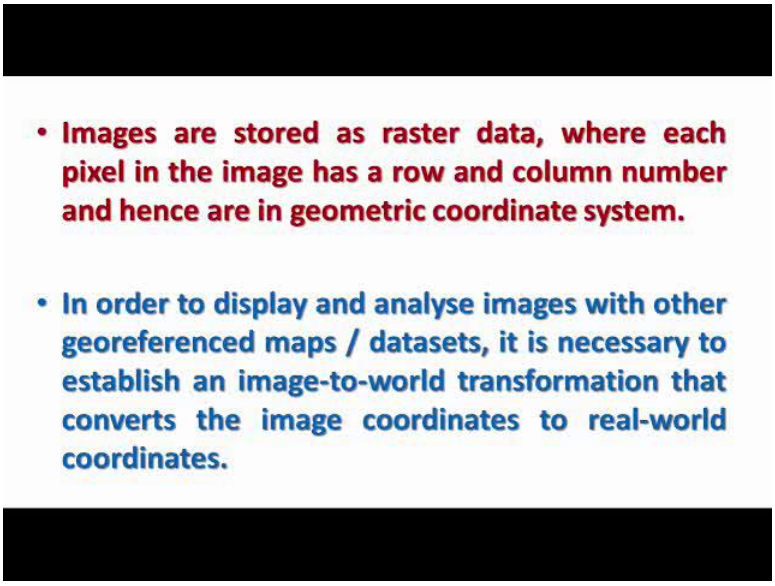

As you know that all satellite images are stored as a raster data, and doing geo referencing raster data is rather easier relatively compare to your vector data and what we do that each because it is a your raster images are made from pixels. So, we use these row number and column number and bring them into from geometric domain to geographic domain. All the three steps three major steps are involved here which we will see one by1, and in order the purpose here in order to display and analyze images with other geo reference maps in GIS it is necessary to establish the image to world transformation, that is converting from transferring from geometric domain to geographic domain and then creating geo reference map or image.

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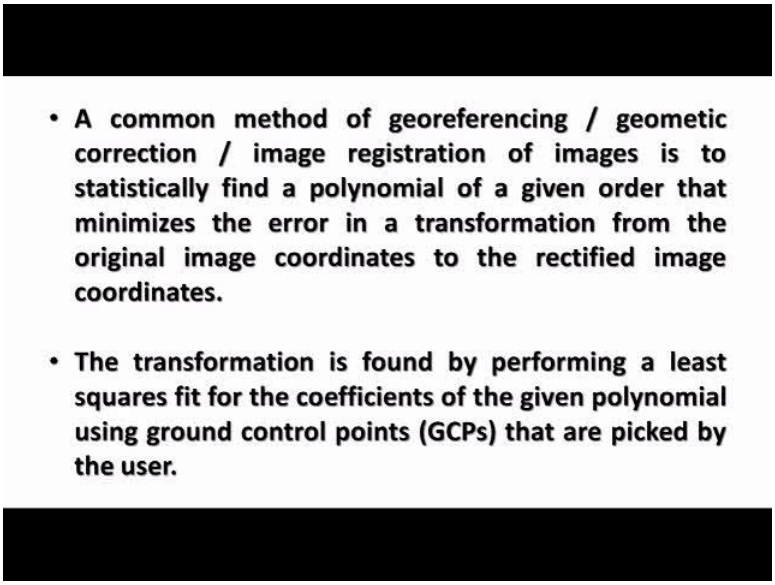

The common method of geo referencing as I have said that is some other terms are also popular like geometric corrections image registration, but nowadays most popular one is geo referencing, when there are three steps are in board let me elaborate on this; first one is registration, registration of your ah the raw map input map to a master one. The master one can be a geo reference image can be a geo reference map or may be Google Earth or GCPS ground control point which might be coming from

other sources and using these GCPS you register your map they say analogy let me give a analogy to this it is something like you know a shoemaker process a shoemaker is having a fresh sheet of leather, and he is having a mould which is made of boot. So, now, he want to you know curve his leather, that leather into shape of a shoe, for this he uses

certain nails first he will put a nail in the front at the toe side and then use a player and pull it little bit put another nail in the heel side and this is what he is doing basically he is doing the registration. Similarly we use satellite image as a rubber seat a digital rubber seat and digitally we do the registration using ground control points ground control points can come from variety of sources which we have already discussed and once this registration is done then throw a polynomial equation, we find that how much each pixel has to be shifted into a target image which is a geo reference image.

So, once a we know the transformation function for each pixel then, question comes the third step the third step is how what should be the value for the target pixel and there is we that process we put under the category of resampling. So, three steps first is registration, second is finding out the transformation function using different orders of polynomial equations and third is resampling. So, we will see one by1, how it is done and once as I have mentioned already that once the transformation is found by performing a least squares fit for the coefficient of the given polynomial which polynomial equation, you will use depends on your data input data, you know that distortions which are present if it is having lot of distortions you are already aware then, you will go for higher order polynomial equations and the depending on the order of the polynomial equations the number of GCPS requires Will also change.

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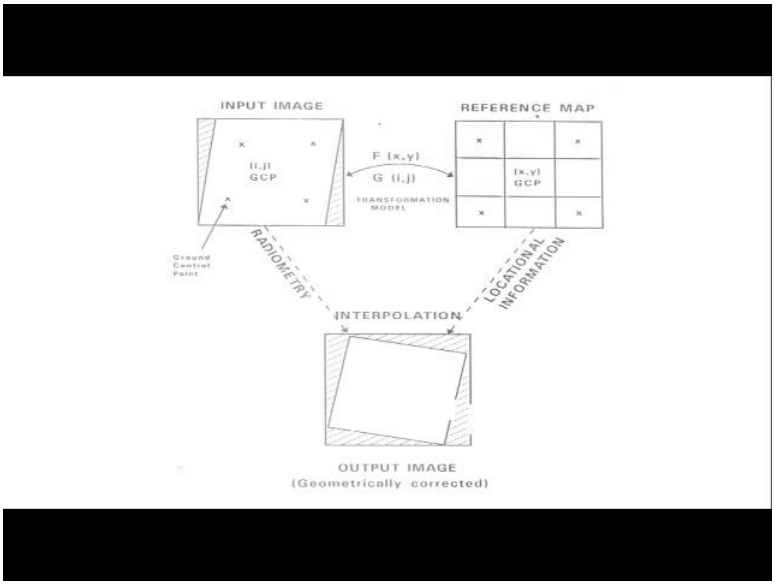

So, that we will also see that how many minimum GCPS are required the basic process is first, step is here to register and he is doing the registration using our ground control points as mentioned here the same as I have given the analogy about the shoemaker he uses nail here in digitally.

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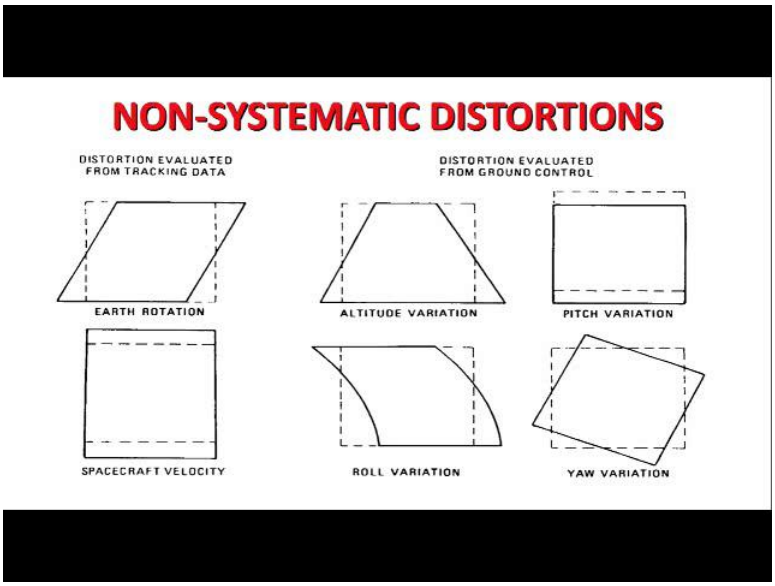

We are using as GCPS putting them and correlating basically the finding out common point, common point life in your satellite which there might be a road crossing or a might be bridge over river.

Now that, bridge you can identify your satellite image and that too you can identify in your master image or master map. So, once this common GCP is found then you register this one with the master this is what is the GCP means here. So, once the registration is done, then through resampling sometimes people also call as interpolation, but it is not exactly interpolation. So, through resampling then you achieve a geometrically corrected or geo referenced image.

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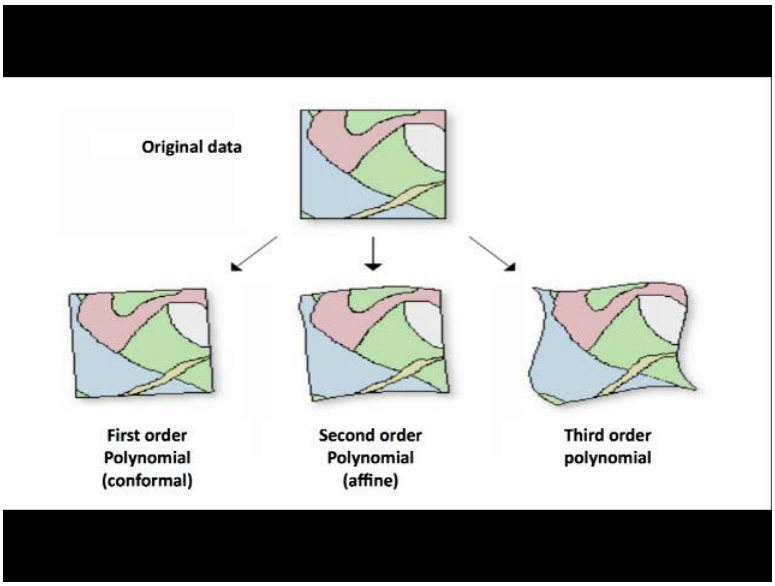

Now, if your data is not having lot of distortions just is a transformation from geometric domain to geographic domain, not scale change and neither rotation is required then the first order polynomial we also call as conformal polynomial can be used to find out the transformation function. If we require change scale change and rotation to our image when we know that it is suffering from some distortions not large distortions then we may go for second order polynomial which is also called as a fine transformation. When we know that our image not only require the transformation from geometric to geographic domain, but the same time there will be change in scale it is rotation and warping also there because of if your image is representing large curve of the large part of the earth then the curvature of earth will also distort your image. In order to correct that one then one should go for third order of polynomial. So, depending on your input map requirements distortion which you are already aware you will choose that particular polynomial.

In many softwares people have even implemented up to twelveth order, but in normal cases even third order is not all the time required. So, even if you can survive with second order or third order, why I am saying that why should not go for higher and higher order if it is required then it is fine if it is not because then once you move one step in higher order then this simple equation You will require number of GCPSs on.

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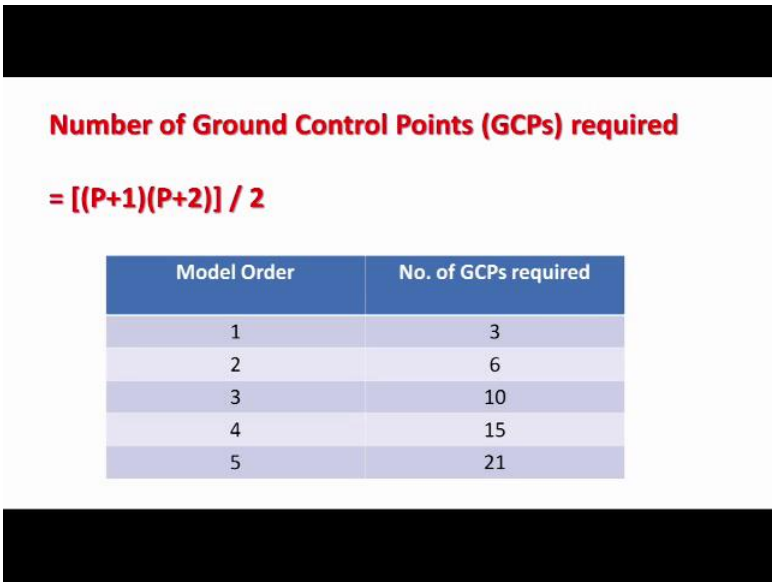

So, for first order only three control points, ground control points are required this is minimum for second order 6 and for third order 10 and then for fourth order 15, you go in higher order more GCPSs are required and in sometimes in a forest area or in a hilly terrain area or in a coastal area sometimes it is very difficult to find out these number of ground controls.

So, for if it is required then you go for higher polynomial equations, transformation functions otherwise it is better to remain between second order or third order. If simple transformation from geometric domain to geographic no scale changes, no rotation, no warping, then first order and this with minimum three points control points you can do the registration.

Now this is the minimum requirement as per practice I always suggest that multiply this by 2. So, if you are going for first order polynomial transformation it is always better for up to go 6 points and for second points may be 12 points and so on so forth, because more number of GCPS you will collect during you are registration higher there is a chance of a higher highly accurate geo referencing and that this accurate geo reference will always help in your analysis when you use this map which is you are doing geo referencing along with some other map in your GIS database.

So, a geo referencing is a common process we do image processing remote processing and GIS plus it is very important and it has to be done very clear fully and very

accurately because highly accurate geo referencing maps will definitely give good results through you are analysis now once the transformation is found.

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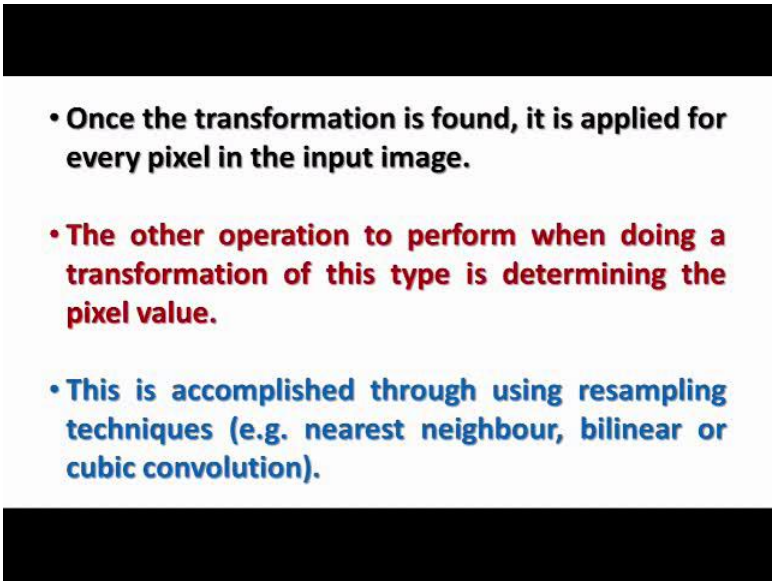

Then it is applied for every pixel in the input image. So, once we know that which pixel has to be shifted where then, this can be achieved by to by taking all these steps to other operations to perform when doing a transformation of this type is determining the pixel value. ecause then now you are reaching to the third step once we have registered we know which pixel will go in the target say empty image, but what valued will carry that has to be also decided and for that it is done through resampling.

In some literature people use word interpolation as already mentioned this is not exact interpolation which we are doing interpolation is little different. So, let us use the term resampling which is more appropriate term for this kind of process in GIS and there are three types of resampling techniques. So, far have been implemented into GIS one is the nearest neighbor which is very simple and quite accurate method of resampling and then there is a little complicated one which is bilinear and cubic convolution. So, all these three you will see and I will explain one by1, this is a common transformation function.

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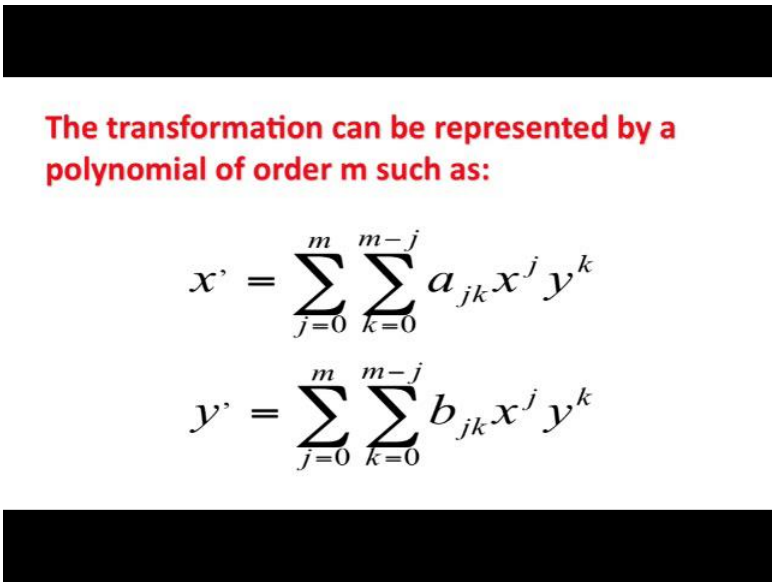

Which is which have been implemented by many GIS image processing softwares the purpose here if you recall your original image which is in geometric domain is having coordinate system is geometric you can address with only column number and line number for these we want to assign geographic coordinates. So, we have to determine x days and y days in order to determine we require certain inputs and through these polynomial equations of different order we can achieve that one, the transformation function there is a second order polynomial equation if an example of arc view is given here.

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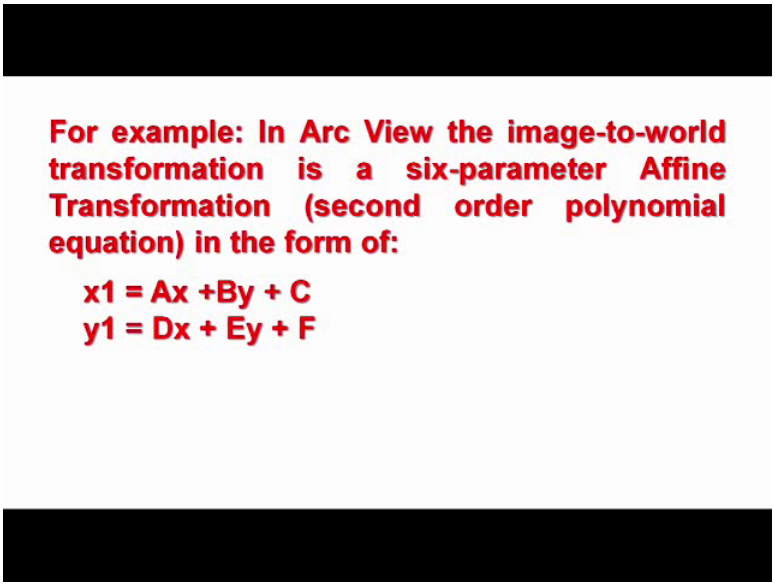

That what we are targeting to determine the geographic coordinates and these are the inputs which goes here and we will see the different these inputs that x1 and y1 are the calculated x and y coordinates of the pixel on the map which is our ah the target one.

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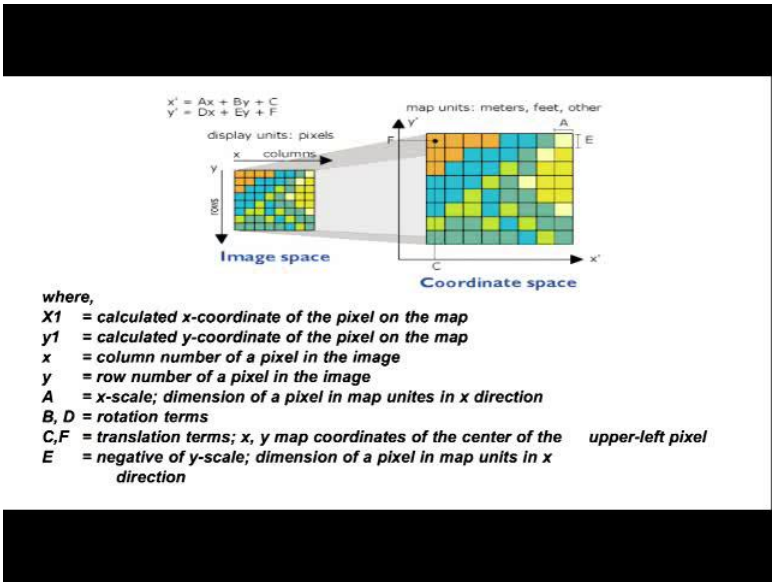

Now, the x column x and y are the column number and row number of input image and a is the scale because it is a second order transformation function. Therefore, we might be doing the rotation of image and changing the scale. So, that component that thing also come has already come in this transformation second order polynomial equation and therefore, that has to be taken care, change in a scale is a dimension of a pixel in map you needs in a x direction and b and d in our equation b and d are the rotation terms because in second order polynomial. We can also not only we can change the scale, but also we can rotate the image. So, the rotation terms are also there and then c and f are the translation term x and y coordinates of the center of the upper left pixel.

Now there is the other issue comes here because a raw image a satellite image always address from top left corner first row first pixel that is the thing, but the generally maps being address from bottom left and therefore, this these this term will come x y map coordinate of the center of the upper left pixel and then negative y scale which is dimension of a pixel in the map unit's and x direction and that has to be also taken care.

So, all this is involve I have elaborated on second order polynomial equation once the transformation function is done this is why y is negative e is negative at y scale because an origin of an image I have already explained to you.

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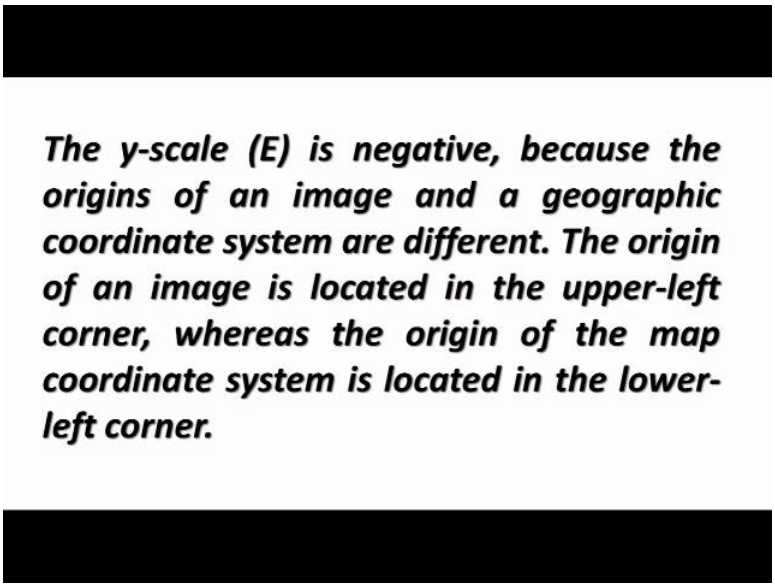

And a geographic coordinates are different an a image originates from top left, whereas you are a map will originate or geographical coordinates system will originate from bottom left. Therefore, there is a negative y scale which is in incorporated in your second order polynomial equation now once a this root mean square is calculated then there are in practice what we do we find out the errors of individual GCPS and one. Suppose I have chosen for the first order polynomial as per the number of GCPS required from that equation which I have shown earlier to you are three. So, first order three GCPS are required once these three GCPS have been registered with the master image then, we start getting our error information. So, point which is the GCPS which is giving the maximum error.

we can correct it remove it and again bring it, but in practice as I have mentioned that multiply by 2; that means, instead of three we should collect 6 and once we see the 6 GCPS and associated root mean square errors we can identify that which one has wrongly registered. So, the GCPS which is giving high error you can get rid of that recalculate it and again recollect it and so, that we achieve within pixel the registration because pixel is unit. So, be we cannot go inside, but at least the dimension error

dimension which comes should be less than what is the spatial resolution of your input image. So, this should be the aim of geo referencing that we should reach to the within pixel the error should be kept to that minimum and total error is computed by as.

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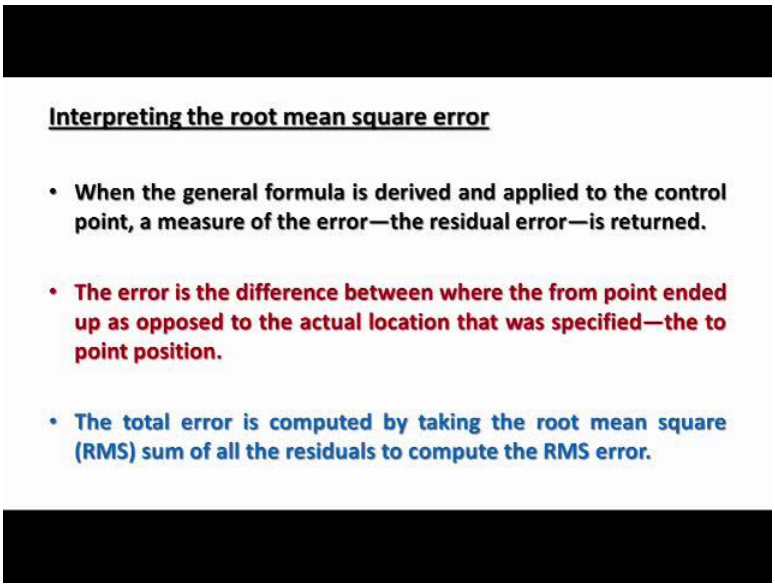

I have already mentioned to root mean square that is sum of all residuals to compute r m s error more number of points when you will collect accurate GCPS, you will collect you will have more chance to remove certain GCPS and certain another important thing collect only those GCPS which are non movable. Because some like if I collect a ground control point or GCP along a band of river you if it is in plain area river migrates. So, if there is a age difference in this master image and you are input image then there might be a shifting of river. So, I will be collecting at two different locations the same GCP which is wrong. So, this will give you a huge RMS, one should avoid the movable object or movable features which you will select for GCP.

The GCPS can be selected as mentioned may be a railway bridge road bridge may be a quarter road crossings and so on so forth. Which are generally fix things are there, if they are not there then we go for say peak of a mountain or a edge or a band in a river hilly terrain because hilly terrain there may not be a migration, but in plain area band of a river should not be taken. So, once this a there the transformation function available to us then we go for ah this resampling technique and lets come to this one what in the back ground in this is the master image which is shown.

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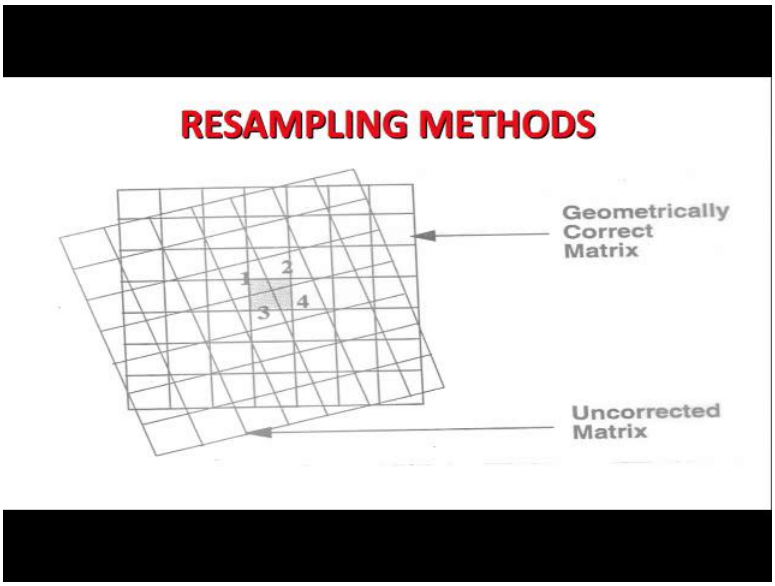

And in the fore ground it is the uncorrected or my input image is there Now, there are four pixels which have been marked 1, 2, 3, 4 and in the center there is 1 shaded pixel of our geometrically correct master image. Now here if you see carefully what you will find that the pixel number 1, 2, 3 and 4 they are overlapping the target pixel, but the pixel number 3 marked. 3 is having the maximum overlap that the target pixel. So, then this situation comes then in a first step in the first type of a resampling that is nearest neighbor the pixel value whatever the pixel value the third marked pixel is having that pixel value is transferred to the target pixel and this is this technique is called nearest neighbor resampling technique.

So, what it will what is done in this resampling technique is overlap is found whichever the pixel is having maximum overlap value of that pixel is transformed to the target pixel and this. What it is nearest neighbor method as also mentioned earlier that the neighborhood and influence of neighbor in pixel values or in GIS analysis matters lot here also that the pixel which is having highest overlap will carry the pixel value for the next target pixel in the second geo referencing this resampling technique which is bilinear technique in which the pixel, which is having the maximum overlap will have the maximum influence for the target pixel in this particular example pixel number 3 will have the maximum width for the target pixel. Whereas the pixel two in this example will have the least and likewise we decide for as per their overlap we decide the weight and accordingly the bilinear sampling resampling is done for the target pixel in a cubic

convolution we will involve 4 by 4 pixel which is in the center having the target pixel and here the weight will be decide based on the distance. So, whatever the you know a pixel which is the farthest at this distance will have the least influence again the pixel which is close to the target pixel having will have the maximum weight and likewise based on the distance the pixel value average pixel value of all these 16 pixels and you can say the weighted average based on the distance will be decided for the target pixel.

So, in nearest neighbor the pixel of your raw image having the maximum overlap will have the carry forward value for the target pixel in bilinear the pixel which is having the maximum overlap will have the maximum weight and the pixel which having the least overlap will have the least weight and it will influence the value and pixel value will be decided in case of cubic convolution as mentioned it is the weight is decided were based on the distance and accordingly things will done. So, let us look here that a nearest neighbor determines the pixel value from the closest pixel to the input coordinate.

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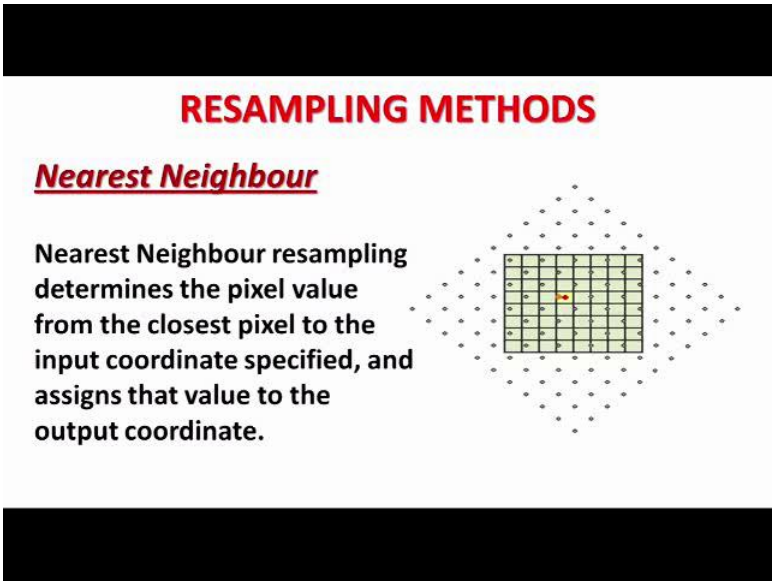

And because in earlier example the pixel 3 had it was the closer because it is it was overlapping maximum and therefore, that value is assigned to the target pixel. Now this we will same time we will be see merits and demerits all these three resampling techniques.

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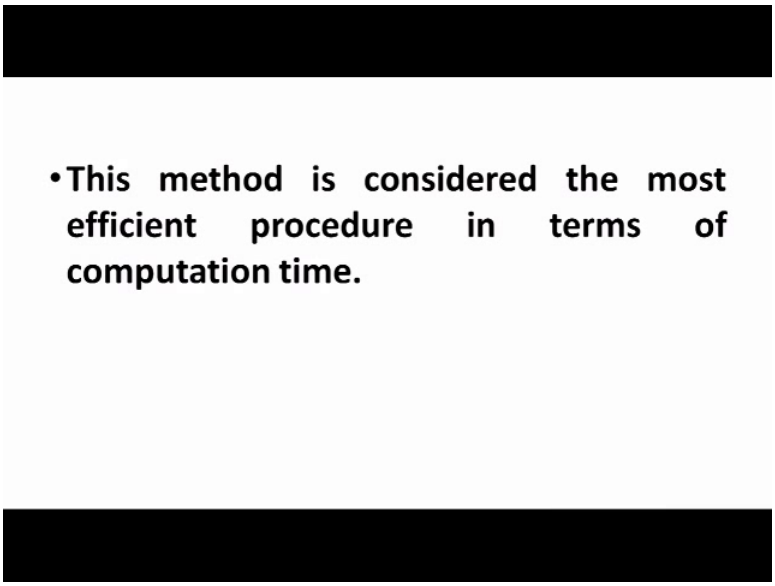

This method is considered the most efficient procedure in terms of computation time because no weighted average no distance calculation and then weight is require like in other 2 techniques and therefore, we say straight forward the pixel which is the closest will carry the value. So, that is why; however, there are though it will not alter the pixel value it will have the same color. So, the quality is not deteriorated if we go for nearest neighbor resampling technique because sometimes you do not want to compromise on the quality of your image and therefore, it is always better to go for nearest neighbor, but it also having some problem as well because nearest neighbor will bring steer step case jagged image as well.

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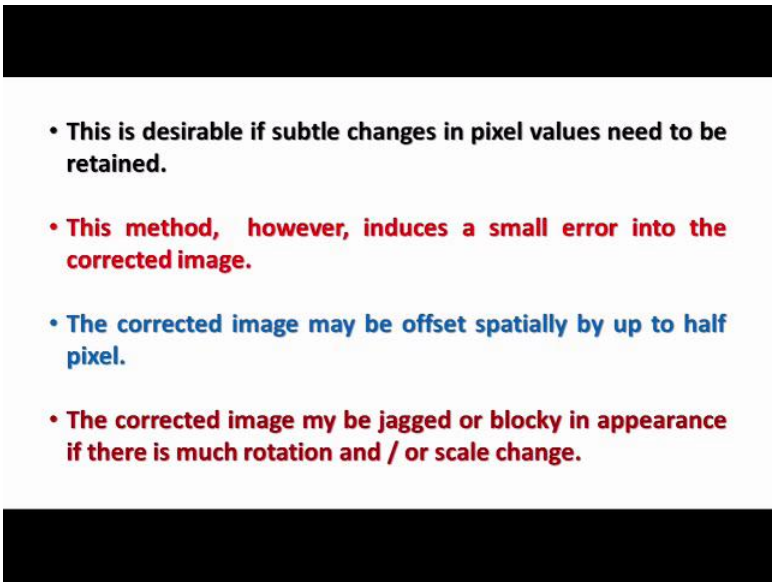

That has to be countered or thought before we chose this one because the corrected image will have offset may be half of the pixel and the corrected image may be jagged or blocky in appearance if there is much rotation or scale changes there. So, my through my experience my suggestion is go for high number of GCPS do the very accurate geo referencing and then go for nearest neighbor. So, what do we you will achieve same time accuracy in geo referencing and also you will not lose the original quality of your image both things will remain intact, but if you go for bilinear.

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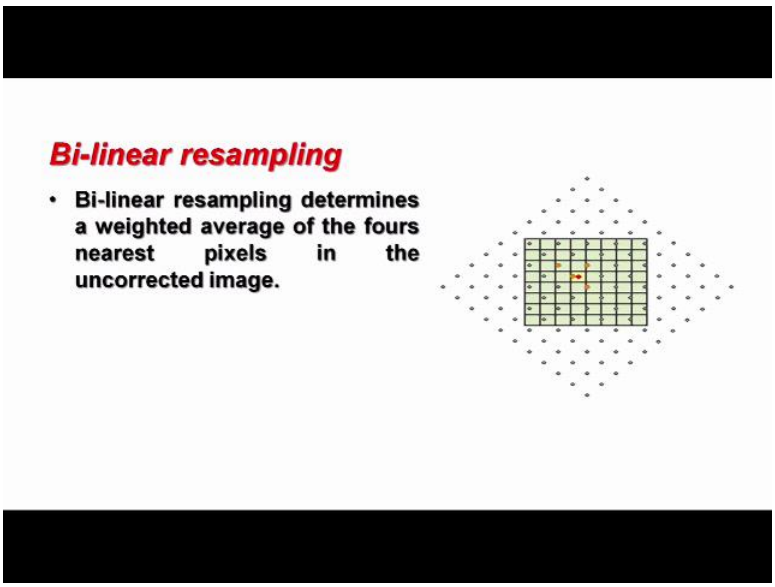

Then four pixels are involved to decide the pixel value for the target pixel and therefore, now little averaging weighted though it is a weighted average what little averaging is done your appearance of your image would be much smoother, but it will more computation time and as we can see here that bilinear resampling generates a smother appearing resampled image is pixel values are altered; that means, they are now modified the original pixel values will not be intact as in case of nearest neighbor.

So, it depends again on your requirements if your happy or satisfied with the altered pixel value by using 4 weighted average pixels values then it is fine otherwise 1 should go only for nearest neighbor, but there are problems with nearest neighbor as well because if lot of averaging is done. Then there might be blurring in the image or lose of image resolution image resolution here means basically the sharpness of the image and this method require 3 to 4 times computation time as you can see that in the nearest neighbor.

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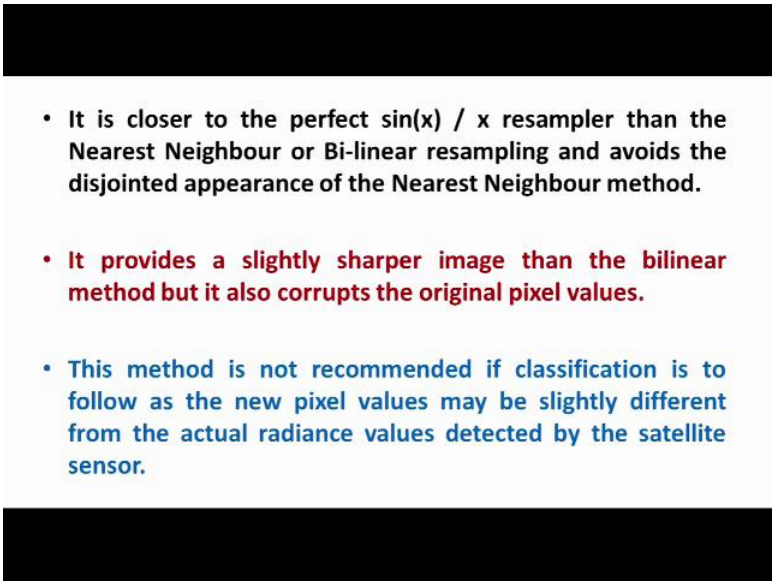

The pixel which have maximum overlap or nearest carry the value, but here 4 pixels are involved their weighted average has to be calculated and therefore, it will take 3 to 4 times computation time these three computation time issues will come, when you are handling large images there it really matters when you are handling small images then any resampling techniques, you use there will be difference only few seconds that depends on you are input image highly accurate registration will achieve more faithful

pixel values from original uncorrected image this condition is true all in 3 resampling techniques that registration of raw image with master image. If it is very accurate then you will achieve again very good results through resampling as well the third and last resampling technique is the cubic convolution as also mentioned that now total number sixteen pixels will be involved lot of calculation is there distance and according to the weight has to be decided this is most sophisticated method which uses the weighted average of the 16 surrounding pixel of the uncorrected image to approximate the pixel value of the new pixel space in the corrected image. This is again will it is more closer to the perfect sin x oblige x resampler then the nearest neighbor or bi linear and avoids the disjointed appearance like in case of nearest the problem, which was there in nearest neighbor will not be there because it will create more smoother image. So, the jig jag or steer step case problem which can be seen after the resampling done through nearest neighbor will not be seen in cubic conclusion and relatively compare bi linear.

It may provide little sharper image, but original pixel values are alter to large extend and this method is not required, if classification is to follow because several times after geo referencing we go for image classification. Say when we do image classification is satellite image is taken there and then we prepare a land use map or a forest cover map and so on so Forth. Then we go for land use our input image pixel values has been altered to large extend because of a cubic convolution resampling technique then you may not achieve very high classification results. So, one has to be careful and that is why it is better to know before you chose a appropriate resampling technique that for what you are doing for what this image is going to be if, it is going to be classification of a satellite data satellite image then nearest neighbor method is very much required and that will really help to achieve relatively highly accurate geo referencing as well as original pixel image or pixel values or image qualities. Of course, the computation time compare to nearest neighbor while linear would be much higher because here.

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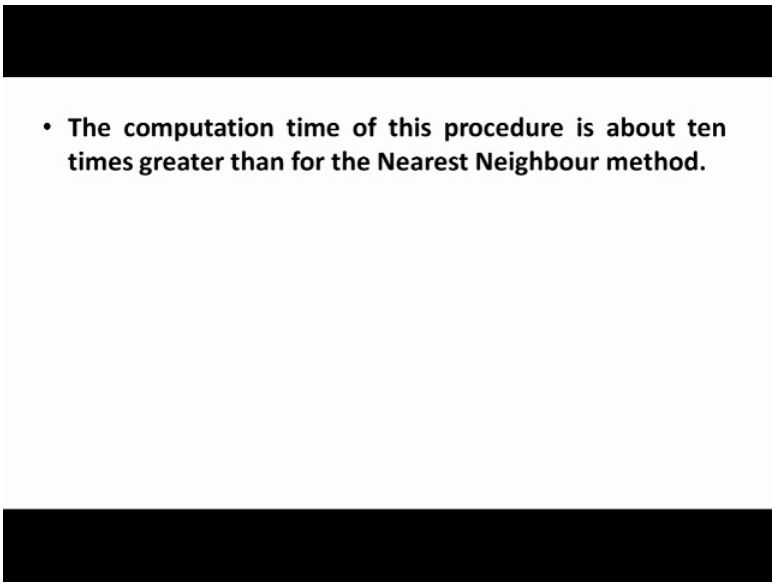

Now, 4 by 4; that means, 16 pixels there distance there pixels there weighted average has to be calculated as I mentioned that it matters that only when your handling large images. So, this brings to end of geo referencing.

Thank you very much.