Remote Sensing and GIS
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Lecture - 05
Error Identification and Correction – II

So this is the second lecture on error identification and correction and in this lecture, we will see more about geometric correction and the geometric error.

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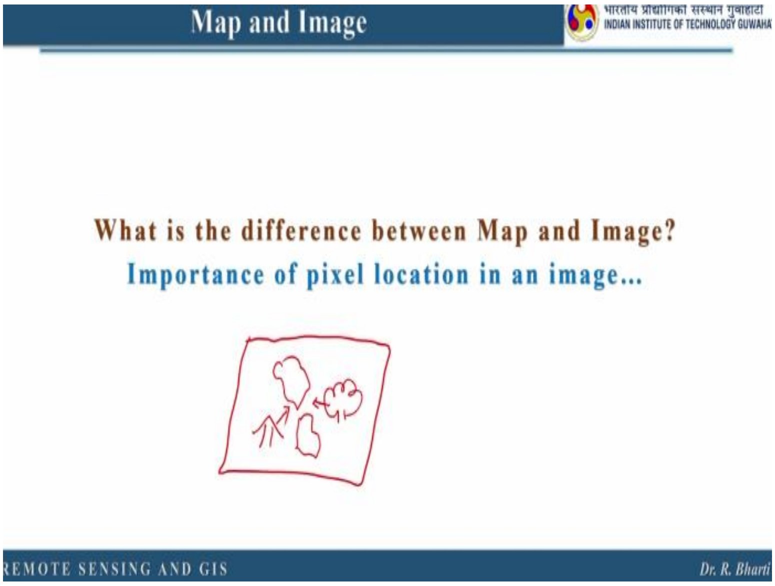

So what do you understand by a map or an image? So that we need to understand very carefully before we start the geometric error and what is the importance of pixel location in an image? So you might have seen a normal image, where if suppose, if there is a tree in that image there is an house and there are some water bodies so which is the actual representation of the ground, but what happens if there is a problem?

Then what will happen, this tree will be more close to this water body or this house can move little bit closer to this water body or this water body can be shifted here. So in any image or map the location of the pixel is very important. So before we start you need to understand with every pixel there are 3 parameters X, Y and Z. So X, Y is your latitude, longitude and Z is your value. So in image form the Z is basically our DN number.

So the DN number, the location of DN number matters a lot because, that defines where your objects or line in the true world.

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There are few examples of map and image. Let me show you first and then I will ask you a question? Like this is one normal image captured by a DSLR or maybe a normal camera.

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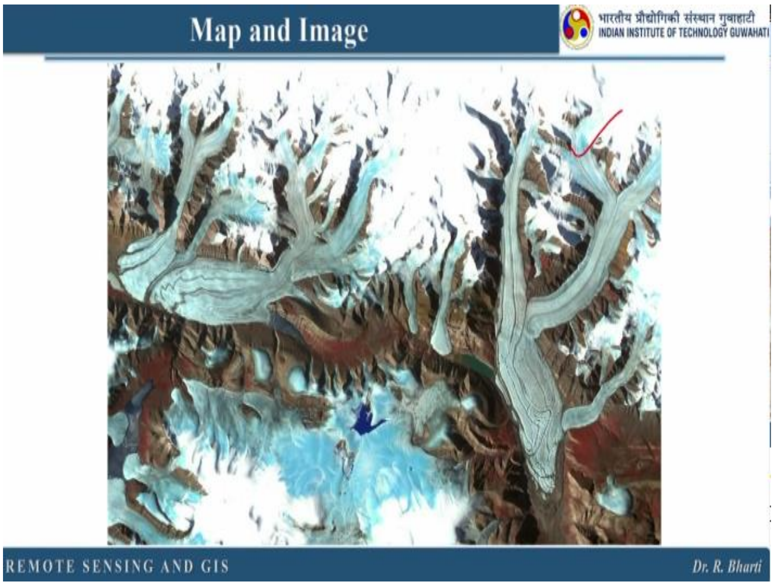

This is one satellite image captured from a sensor located in the space, so here what is the importance of pixel location? Now you can correlate with my logic suppose this water body, especially the location of this water body is here that is the true location of this, but if there is a slight change in the orientation of this photograph or this sensor image what will happen this may get shifted somewhere else.

Right or this part maybe gets skewed or if it is skewed, compressed or stretched what will happen the actual representation of this area will not be there in your image. So that is why it is very important to make sure whether each pixels are located in it is own position or it is lying somewhere else that error we need to take care. This is another example.

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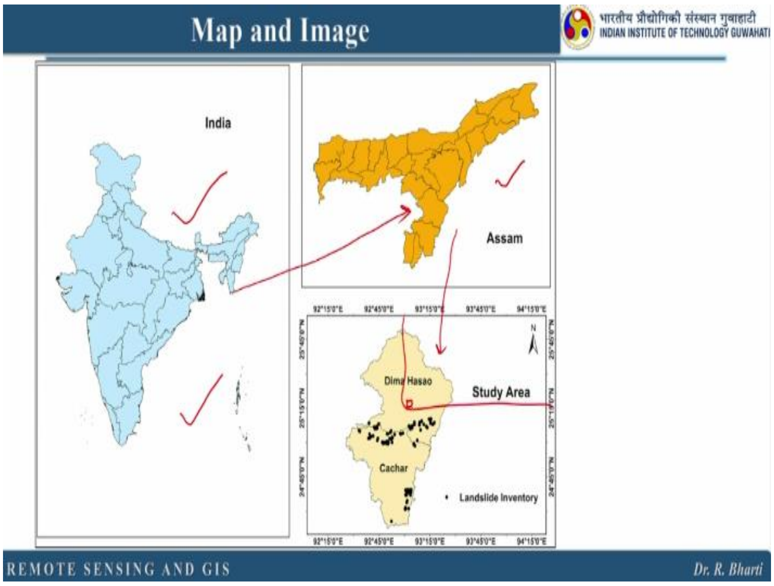

Here, this is the general way, we represent our study area, so this is the India and from India, this is the part which is represented here and from this the your actual area. So here the difference between map and image, you will understand. So here this is one image why I am calling it an image? Because it does not have any location value, so we do not know whether this image is a true representation of India or it is a wrong representation of India.

So as well as this particular image, that is also it does not have any location value, but when we see the study area, here all the latitudes, longitudes are mentioned, that means if you want to identify any particular position of a pixel, then you can easily do that. So you can see where it is located and you can easily find what the latitude longitude value for this?

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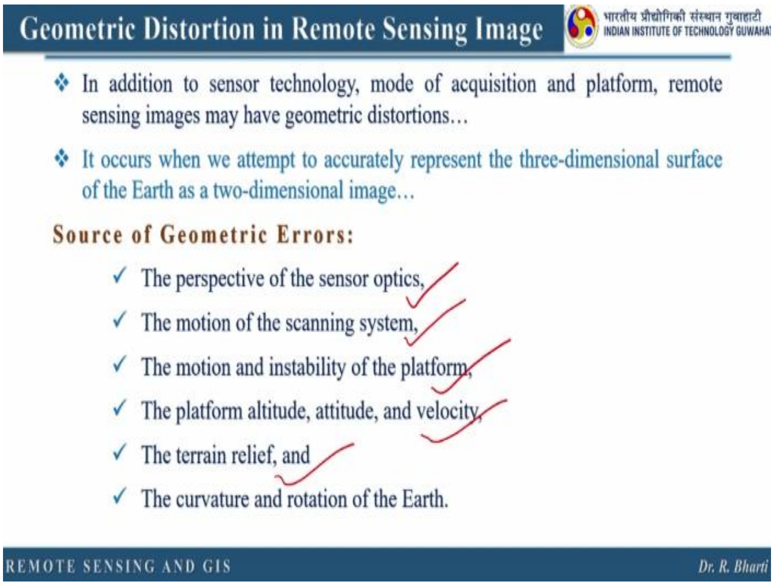

What is the geometric distortion in remote sensing image? So, in addition to sensor technology mode of acquisition and platform remote sensing images may have geometric distortion. So geometric distortion, there is a problem with the location of the pixel, it occurs when we attempt to accurately represents the 3-dimensional surface of the earth as a 2-dimensional image.

Because whenever we capture any image does not matter whether from space or from airborne or from your normal camera or mobile, so always what we do, we convert 3-dimensional image into 2-dimensional. So, then the transformation of 3-dimension to 2-dimension that creates lots of problem. So, what are the sources of geometric errors? So first one is the perspective of sensor optics, whether optics are basically aligned properly or not.

Then next is motion of the scanning system, in case of satellite images, whether the satellites are moving in it is pre-defined velocity or it is changing with time So, if it is changing then calibration everything has to change, so in case only velocity has changed because of some abnormality in the system, then you will have problem of geometric distortion. Then next is motion and instability of the platform. So, whether your platform is properly stable or it is going to change with time or with respect to the ambience.

So, in case of airborne survey what happens we are doing this mapping from the our atmosphere, so the effect of atmosphere will be there so flight may change it is attitude. So that may result in changing the pixel orientation and the position. Then next is the platform altitude, attitude and velocity then terrain relief, terrain relief, whether it is a hilly area or flat land that also creates lots of problem the curvature and rotation of the earth.

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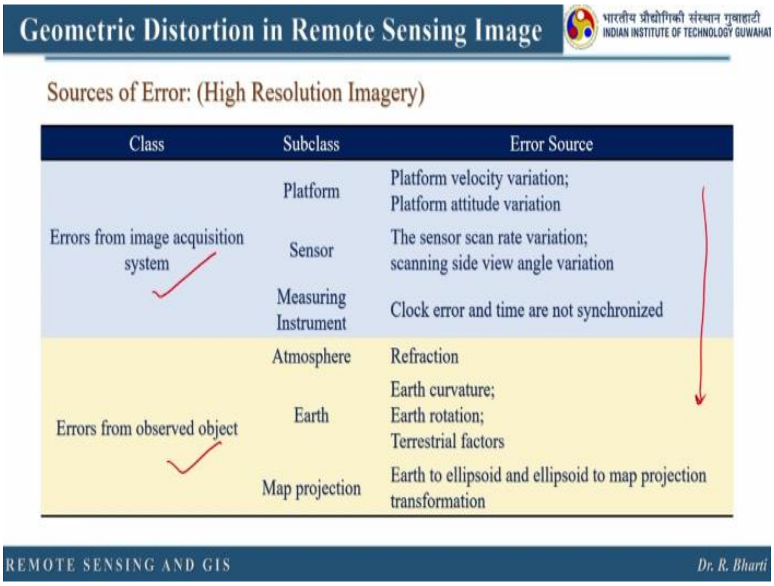

Class	Subclass	Error Source
Errors from image acquisition system	Platform	Platform velocity variation; Platform attitude variation
	Sensor	The sensor scan rate variation; scanning side view angle variation
	Measuring Instrument	Clock error and time are not synchronized
Errors from observed object	Atmosphere	Refraction
	Earth	Earth curvature; Earth rotation; Terrestrial factors
	Map projection	Earth to ellipsoid and ellipsoid to map projection transformation

There is a table where you can see sources of error like errors from image acquisition system and errors from observed object, so this is a classification of sources of error and specially in case of high-resolution imagery.

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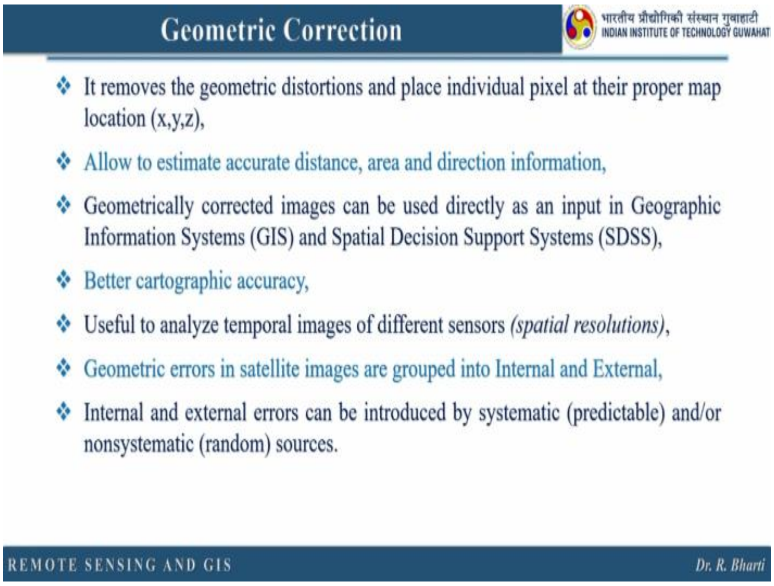

Now what we do exactly in geometric correction, so here what we do is we remove the geometric distortion and place individual pixel at their proper map location that is XY and Z write X, Y is your latitude, longitude Z is your DN number. Then it also allows to estimate accurate distances area and direction information. So, I will give you some example like there are 9 pixels and this pixel is having a house and you want to estimate the distance between these 2.

So, this is the truth representation if there is a change in the position because of the change in the altitude, attitude or different parameters, then this may appear in your image like this and houses here and houses here. So, in this case the distance from this to this is different and from this to this is different. So, but actually this is the correct one, this is the wrong one.

So you need to take care of this geometric correction then only you can truly accurately estimate the distance area and direction information, because normally when we capture the images from satellite what happens it may appear as a normal photograph, but once you do the geometric correction, you place the individual pixel in their own location, then in that case, let us say this is the image captured by your satellite.

So, without geometric correction this may appear as a normal image, but once you correct it geometrically then it may appear like this, and this is the actual orientation of this area in that particular location. So, the purpose of this is, if you do the geometric correction, if you place all the pixels in their own location, then you can easily find out what is the X and Y and Z value of this particular pixel and X Y value can be used to locate this pixel.

In the field using a GPS because when you know X, Y you can easily do that now a days you must be familiar with google earth. In google earth instead of writing the location name you can write latitude, longitude and that google earth will take you to that particular location, so how it is doing because the whole system is defined in terms of X and Y. So this is the advantage of doing this geometric correction.

Now the third point is geometrically corrected image can be used directly as an input in geographic information system and spatial decision support system. So what does it mean that from satellite you have derived a image and from image you have derived some information, like what is the area of forest? What is the area of this particular river? How much water is there? Or what is the length of this River?

So, those are the information derived from satellite image and that will be part of your decision support system or in you are big problems, it is going to be used as an input. So in that case you need to make sure that geometric correction has been applied on the collected image and better cartographic accuracy. So it will represent the true area or true representation of the area, then useful to analyze temporal images of different sensor.

So if you have X, Y and Z sensor and they are measuring the images in different wavelength region depending upon their specification of this same area then you can have multiple information from across the wavelength and that you can compare once they are geometrically corrected, then only the one image captured by X will be exactly covered by Y and then exactly covered by Z.

So then, this is the case when you have geometrically corrected image. Now geometric error in satellite images are grouped into internal and external categories and internal and external errors can be introduced by systematic and non-systematic or from both. So you have to correct for internal and external errors.

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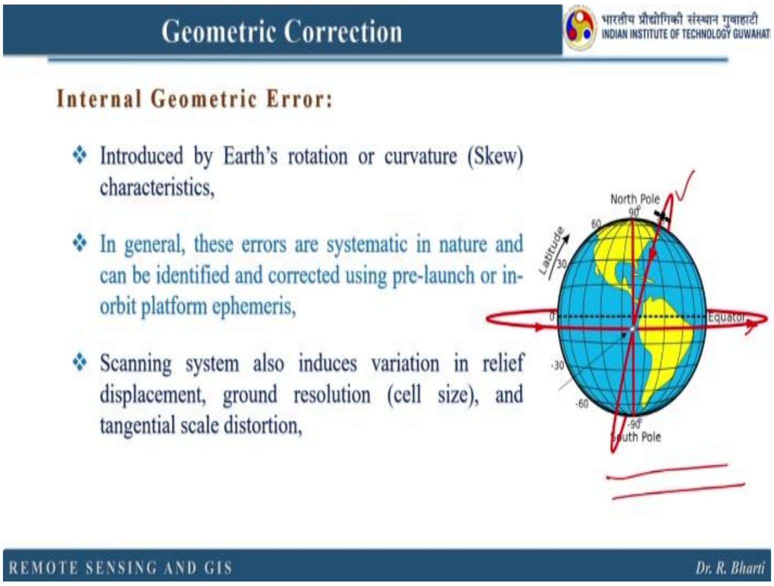

So this internal geometric error, it is basically introduced by earth rotation or curvature, So this is one example or this is the example to explain this particular statement where the rotation of the earth is responsible for giving the error in your measures data. In general, these errors are our systemic in nature and can be identified and corrected using pre-launch or in-orbit platform ephemeris, like here basically, you know, what is the rate of this movement, and what is the rate of movement of your satellite here?

So if there is a change then you can easily predict that one or estimate that one scanning system also induces variation in relief displacement ground resolution and tangential scale distortion.

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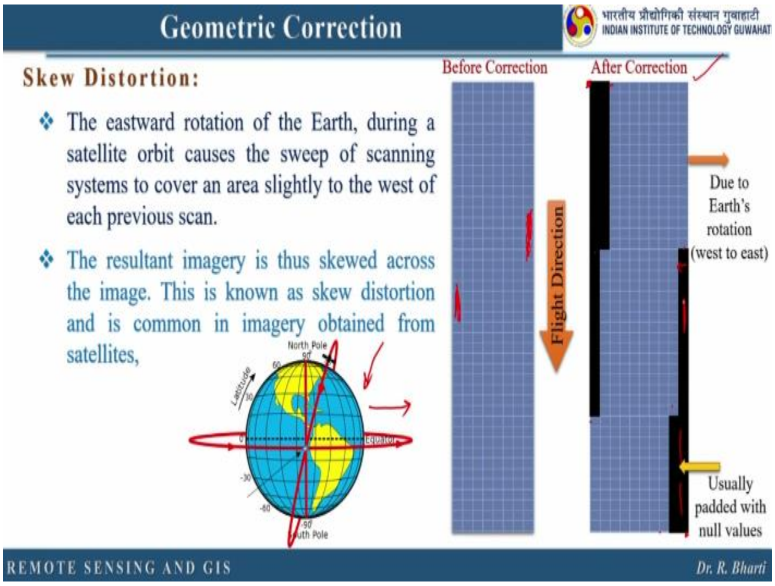

So skewed distortion, so let us see what it says is the eastward rotation of the earth during a satellite orbit causes the sweep of scanning system to cover an area slightly to the west of previous scan, so what is happening? So when you just look at this figure, so what is happening this satellite is capturing this particular area and how it is generating the image. So this will capture this so line wise let us see this is push broom sensor.

So first one, second, third so slowly it is moving in this particular direction. So this is the direction. Now here you can see or you can visualize like if it is capturing this particular image and when it is coming to this particular position and then it is capturing this particular area, so what will happen due to the movement of this earth there will be change in the position like this is the first then, second will be slightly this side and third will be slightly this side.

So why, this is because of the rotation of the earth and movement of this satellite. So this is one better example to understand this problem. So here this is the image before correction. So when we capture image, it will look like this and we thought that, this is very good and image is properly aligned with each other, but you can find out there is a change in the position of the elements right, elements means pixels or in terms of objects, so there will be some mismatching here right in the corner pixels.

So why it is so because it is moving, it is moving and satellite is also moving. So in this case what is happening? There will be slight change in the position and the coverage of this satellite. So the resultant imagery is the skewed across the image. This is known as skew distortion and is commonly a common in imagery obtained from satellite; here this is the corrected so after correction, so you can find out how much it has been shifted. So this is because of the earth rotation and usually padded with null value.

So when you do the correction, there will be some blank pixel here, because image will start value will start from here to here, but actual measurement is from here to here, So these blank pixels will be assigned some null values.

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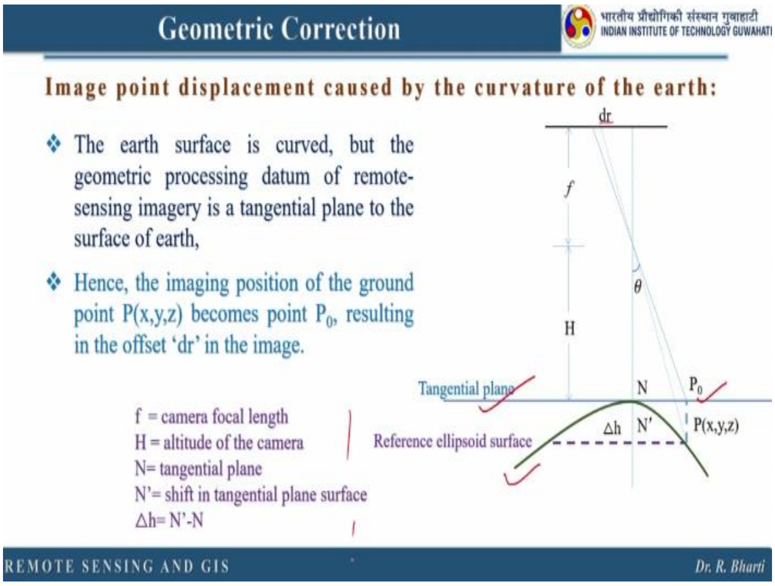

Image point displacement caused by the curvature of the earth, here the earth surface is curved, but the geometric processing, datum of remote sensing is a tangent plane to the surface of the earth. Hence the imaging position of the ground point P becomes point P0 resulting in the offset 'dr' in the image, you can see here and here is your P0 this is your reference ellipsoid system, this is your tangent plane.

So this is very easy to understand, but it is very important in case of satellite images because you have to take care of all this displacement and skewness and were all this detail are written here, you can go through this.

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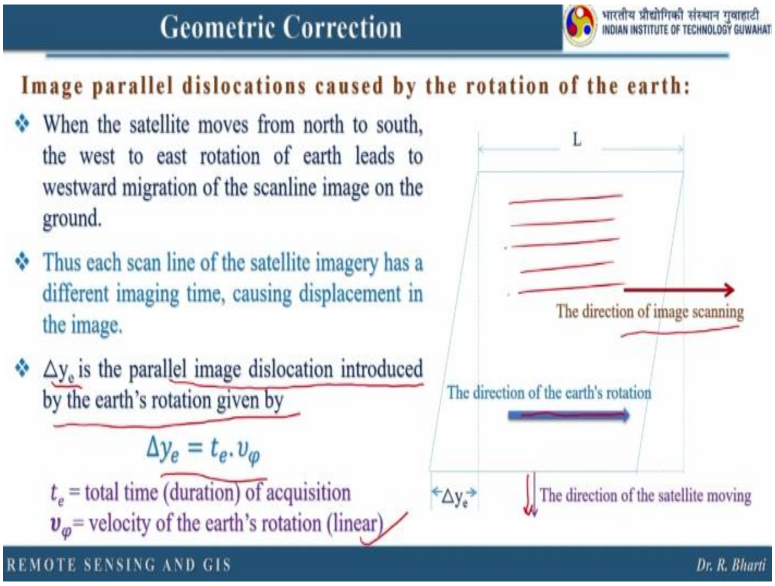

Image parallel dislocation caused by the rotation of the earth when the satellite moves from north to south, the west to east rotation of the earth leads to westward migration of the scanning image on the ground that you have already seen that in the previous slide, how the image looks like when there is a change. So this each scan line of the satellite imagery has a different Imaging time causing displacement in the image.

And here, this is the parallel image dislocation introduced by the earth rotation given by this equation where total time of the acquisition is used and velocity of the earth rotation and we assume here linear, so and in this image, you can see this is the direction of image scanning. So images scanned like first, second, third, fourth, 5 and this is the direction of your earth rotation and this is the direction, where your satellite is moving. So then your image will be generated. Now, you can correlate with this particular image that how it has been generated.

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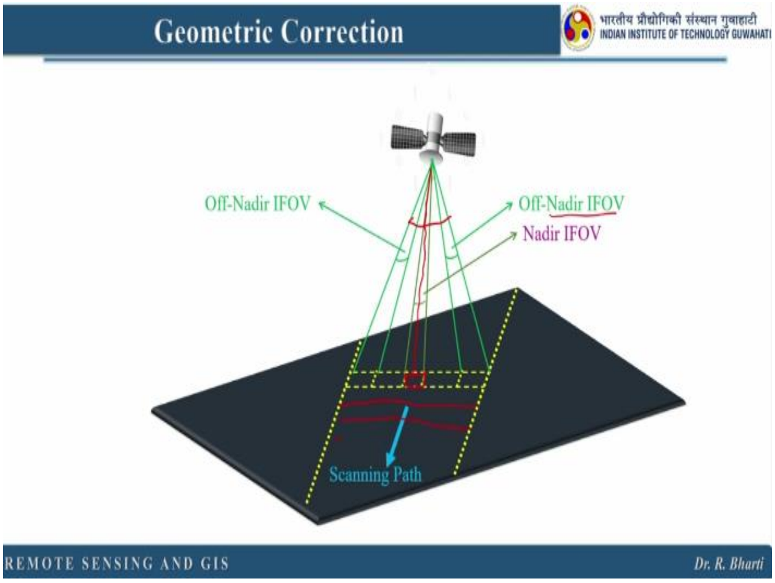

Now, there are few very important concepts which you need to understand that is first is what is the nadir looking pixel? what is the off-nadir pixel? What is FOV, IFOV and how it is going to affect the images acquired from the space or does not matter whether from airborne sensors, So, if you see, this is the nadir looking pixel, which is here, So that means this, if you draw a line here, this will be perpendicular to your surface and other pixels which have been seen from this particular sensor they are called off nadir.

So each pixel is captured by a detector and that angle at which it is looking at the surface that is known as IFOV and the total angle looked by the sensor that is your FOV, and this is the scanning path, so next pixel will be generated here, here like this. It will generate the whole image.

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If you see this particular image, so you can see there are pixels where you cannot see the sides that means those are the pixels looked vertically down but there are few places or there are few photographs in which you can see the sides right like here. So what does it mean that means, the nadir was somewhere here and from here images have been captured. So just extend this vertically up and then you see then, you can visualize so here if you have this image, there will be no side view for this pixel.

But pixels away from the nadir they may have information from their sides, so that indicates these sensors, which have been used to capture this image they were not nadir looking. This is another example, when you change the location of the satellite, your capture angle will be different.

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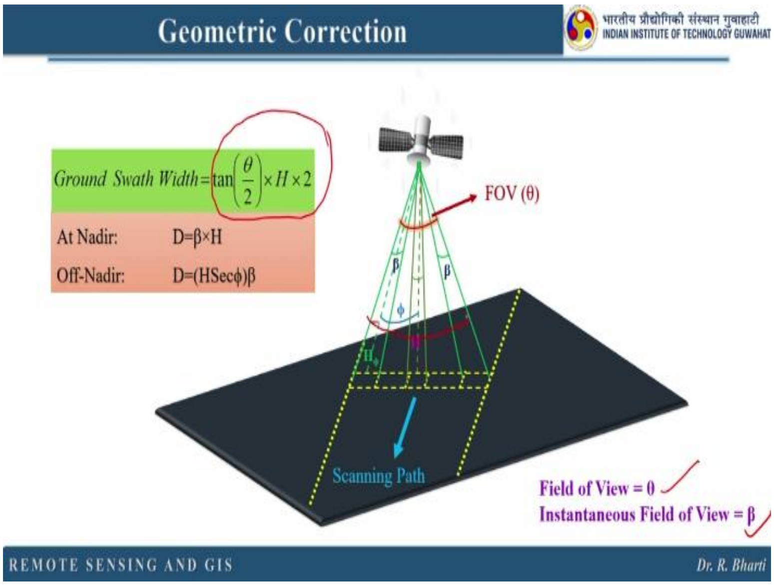

Now after this you need to know how these IFOV and the nadir looking pixel and off nadir looking pixels are going to affect the measurement on the ground. So here you can see the field of view, we have defined with theta and IFOV we have defined with beta. So if you want to calculate what is the ground swath width? That means, you have to use this particular equation, 2 tan theta by 2 into H and everything is known H is the basically your altitude of the satellite.

But at nadir D = beta multiplied with H, but off nadir D = H Sec Phi multiplied with beta. So this is how your pixel size will vary in case if your sensor is looking with some angle or in case of vertical photographs this error will be minimum. So there is a question?

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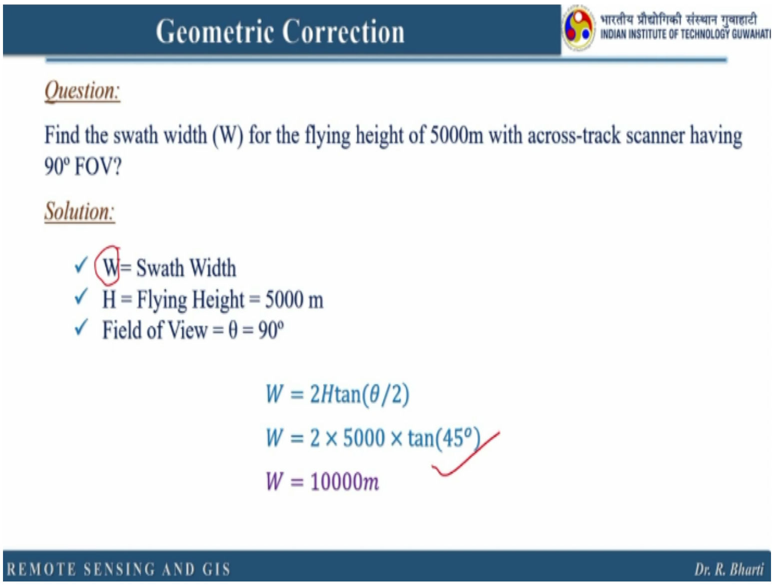

Like, how to find swath width for a flying height of 5,000 meter width across track scanner having 90 degree of FOV? So how to solve this, so these parameters you can easily use in your equation and you can find out what is the swath width and here we have used W to define this swath width. So W = 2 H tan theta by 2 and here H is basically 5,000 meter and theta is basically your 90 degree. So theta by 2 will become 45 and then you can calculate W = 10,000 meters.

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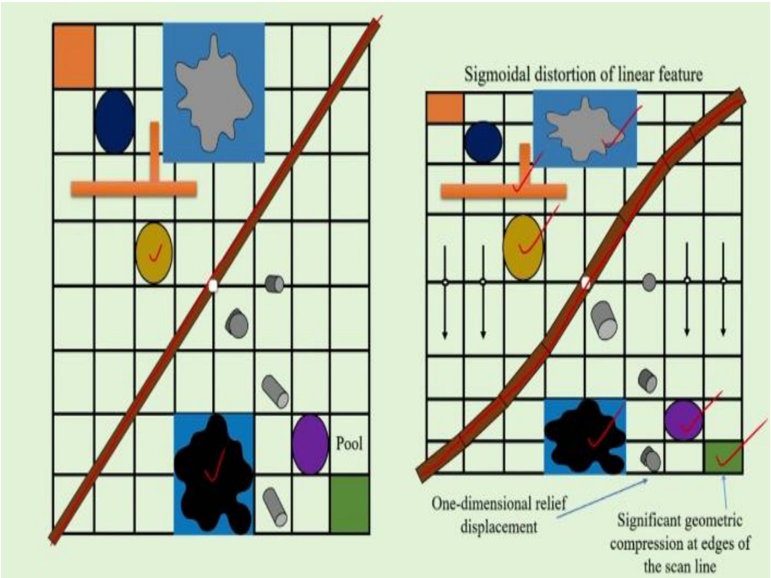

Now in this slide, I want to highlight, what kind of error this geometric error may introduce in your image? So if you see this particular photograph and I would say this is the actual scenario in the ground. So all the objects they are lying somewhere this is the orientation and this is the shape size of the particular location. Now, how they are going to change when you are having geometric distortion in your image?

That you can visualize here, so this road which was supposed to be straight, now here it is having some angle and all these objects are basically distorted, so they are not in their own position or in their own shape and size. So that means this is a very serious problem in your satellite image.

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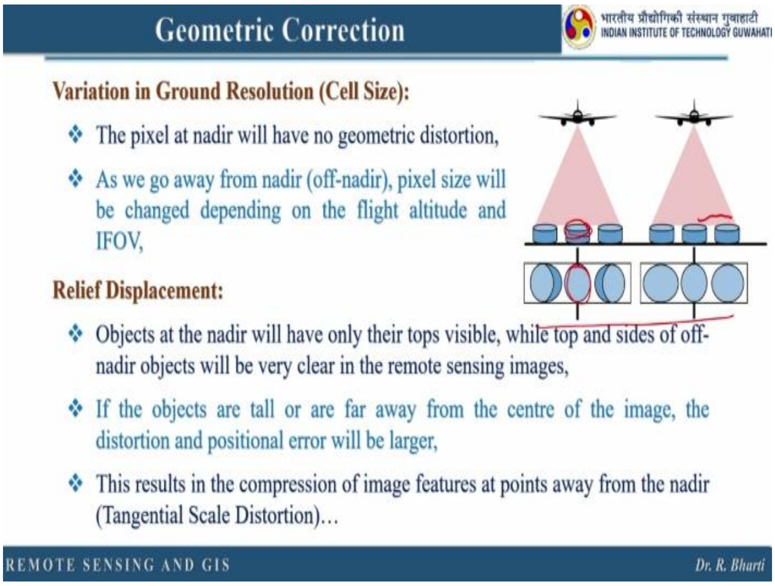

And now, there is another concept like variation in ground resolution cell size, how this is changing? That is because of the nadir looking and off nadir looking detectors and here you can see if you have nadir looking basically this will exactly represent the area or the object. But when you have off nadir, then it can have this kind of effect. The pixel at nadir will have no geometric distortion as we go away from nadir that is off nadir, pixel will be change depending upon the flight altitude and IFOV.

I think it is clear, now the next concept is relief displacement. Object at the nadir will have only their top visible, while their top and side of off nadir objects will be very clear in the remote sensing images, as showed you those three photographs. Now next is, if the objects are tall or are far away from the center of the image, the distortion and the positional error will be larger, why because as you go away from the nadir you will have more error.

The results in the compression of image feature at points away from the nadir that is known as tangential scale distortion, this is the example I showed you earlier and now this also explains the same logic.

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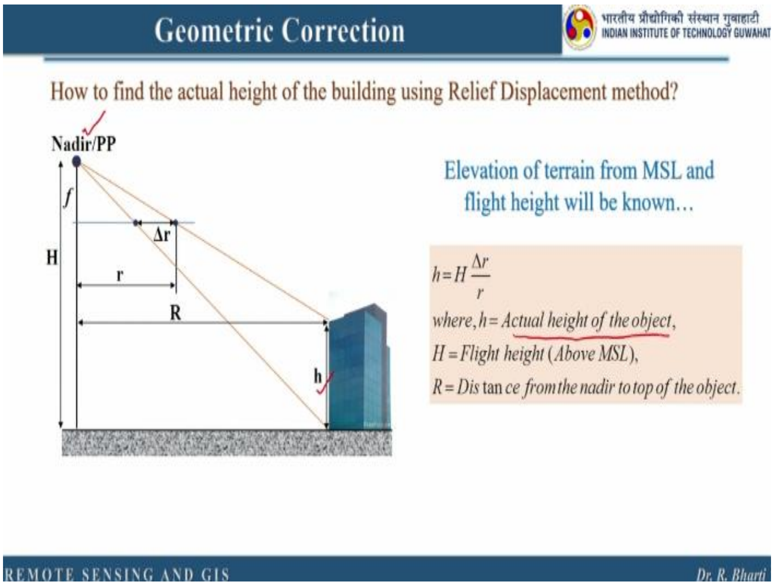

So based on this fundamental, can we find the actual height of the building using this relief displacement method? Because as I told you errors can be considered in positive manner also and negative manner also. So here when you have off nadir pixels or off nadir images and basically the sensor has use some angle to generate that image. So those images can be used to calculate the height of the building.

So you can see here, that these buildings from here to here it is visible all these tops and bottom and you know the center pixel is not this one, it is somewhere else, where you do not have any side visibility. So, for an image where the nadir pixel is different or away from your target, so here you can see this is the nadir, there is the nadir of this particular image and this is the small edge of this building.

So all these information can be used, in this case you can easily find out the elevation of terrain from MSL and flight height. If other parameters are known and if these 2 parameters are known then you can find out what is the height of the building. So you can use this equation and where h is the actual height of the object, which we want to calculate and H is the flight height above MSL that is known to us and R is the distance from nadir to top of the object.

So this is the R so if have all these parameters you can easily find out what is the height of the building from a satellite image or aerial image.

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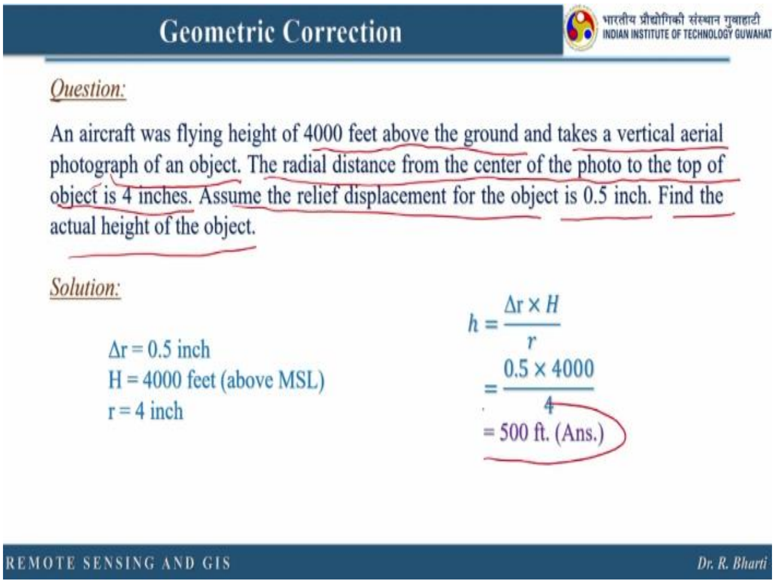

So here the question is an aircraft was flying with a height of 4000 feet above the ground and takes a vertical aerial photograph of an object. The radial distances from the centre of a photo to the top of the object is 4 inches, assume that relief displacement for the object is 0.5 inches. Find the actual height of the object? So, how to do this? So here delta r is 0.5 inch, H = 4000 feet above MSL and small r is 4 inches, so you can easily find out what is the height of the object, so this is 500feet.

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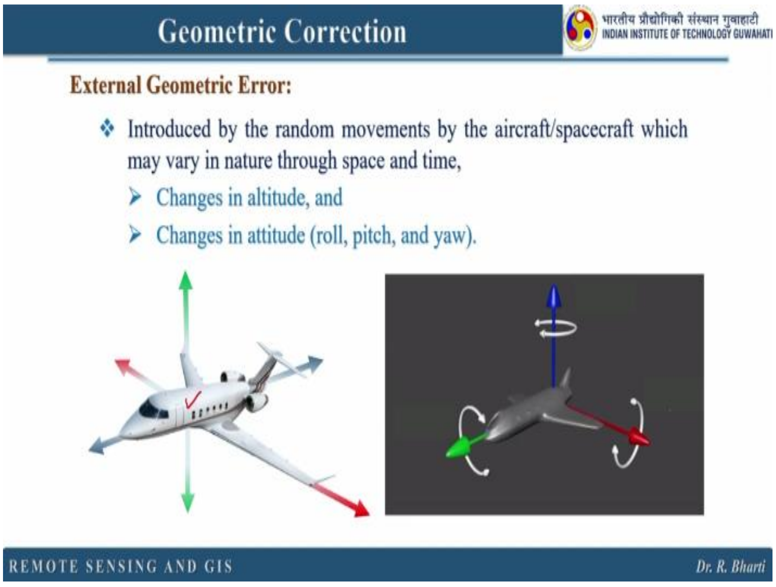

So this is introduces in the random movement by the aircraft or a spacecraft, which may vary in nature through a space and time right. So that is the definition of randomness and here you can see there is a plane, in case of airborne remote sensing or you can consider a satellite here, instead of this aeroplane. So you have X, Y and Z axis. So basically, this plane can move in any of these 3 directions and because of that there will be change in the angel of the measurement.

And because of that what will happen? You may have distorted images. I hope this is clear from this animation in the image. So because of the change in the altitude and change in attitude, in attitude how we define altitude, altitude is the height of the sensor or the satellite from where we are taking the measurement and the next is attitude, attitude is basically what is the position or the behavior of that particular platform in X, Y and Z direction, so here you have roll, pitch and yaw.

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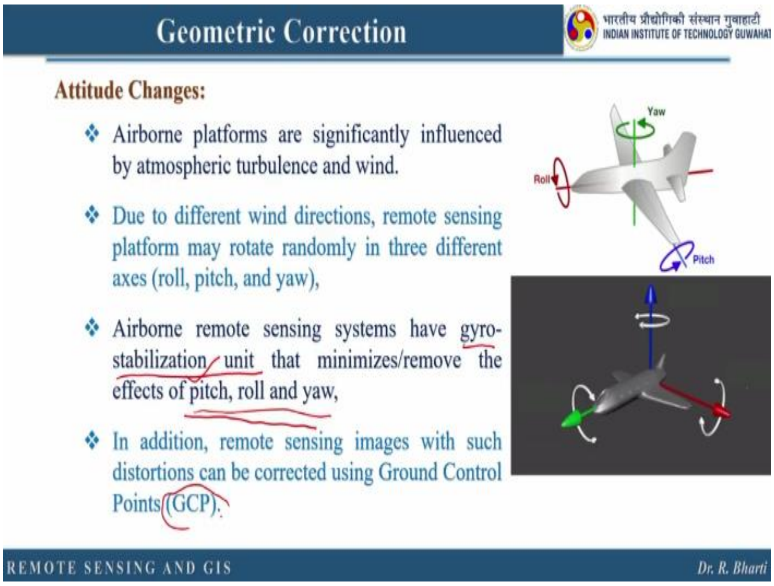

Let us see altitude change. So when we have altitude change then what will happen there will be change in the pixel size because this ground swath width depends on this theta and H. So theta is not going to change does not matter whether your satellite is moving down or going up. But when it is moving up and down or if it is changing it is path then what will happen this H will vary so your pixel, which is a representation of the ground.

So the spatial resolution of remotely sensed images a function of IFOV and the altitude above ground level that is capital H here. So the airborne platforms are significantly influenced by atmospheric turbulence and wind. So here when there is a change in the wind direction or strength of the wind, so then what will happen, this may change its attitude. So due to different wind direction remote sensing platform, may rotate randomly in 3 different axes roll, pitch and yaw.

Airborne remote sensing system have gyro-stabilization unit that minimizes or remove the effect of these 3 axes. In addition, remote sensing images with such distortion can be corrected using ground control point. So ground control points are the location measured in the field with their parameters, like whether it belongs to forest, whether it belongs to road, whether it belongs to temple, whether it belongs to a field, so that information is captured along with latitude, longitude.

In image, if you know that this pixel is supposed to belong to forest area then you can match these ground control points and that pixel location whether they are same or different if there is a change in the latitude, longitude value of the image and the ground then you need to take care or you need to adjust the error of the image. Because the measured values the ground control points, they are the true values.

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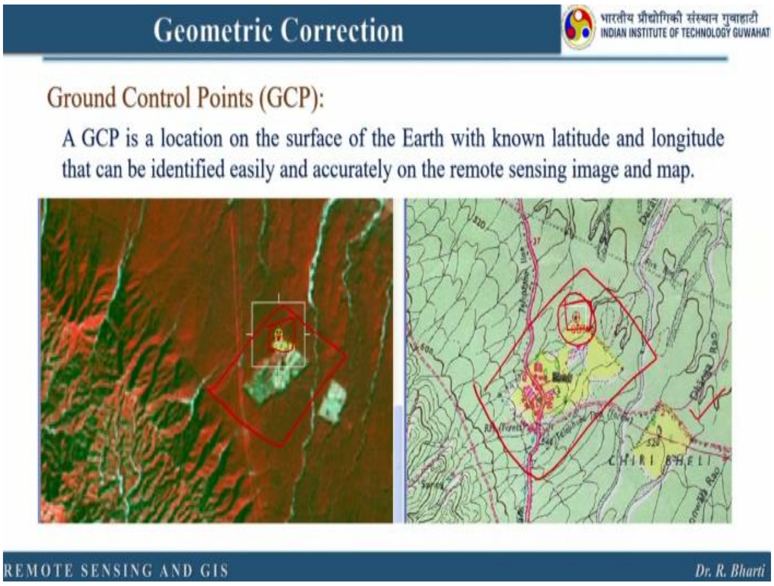

So, how do we define this Ground Control point? So a GCP, the ground control point is a location on the Earth surface with known latitude and longitude values that can be identified easily and accurately on the remote sensing image and map. So suppose if you have a toposheet, toposheet is developed by survey of India and where we have the actual location of this particular piece of land and for the same area you have satellite image.

Now, you can see the location of this particular corner, and this particular corner can be identified easily on the map as well as on the image. So this is, this image is basically a toposheet but each pixel is having X, Y and Z value here you have only Z value, which is measured from this satellite. And then sometimes when you have X, Y even that may have some error, so what you need to do you need to correct this with respect to ground measured values or from a map.

So when you correlate these 2 values and then if you are able to identify a relationship at which rate this particular error is occurring in this particular image, you can easily correct that one. So how do we select GCP?

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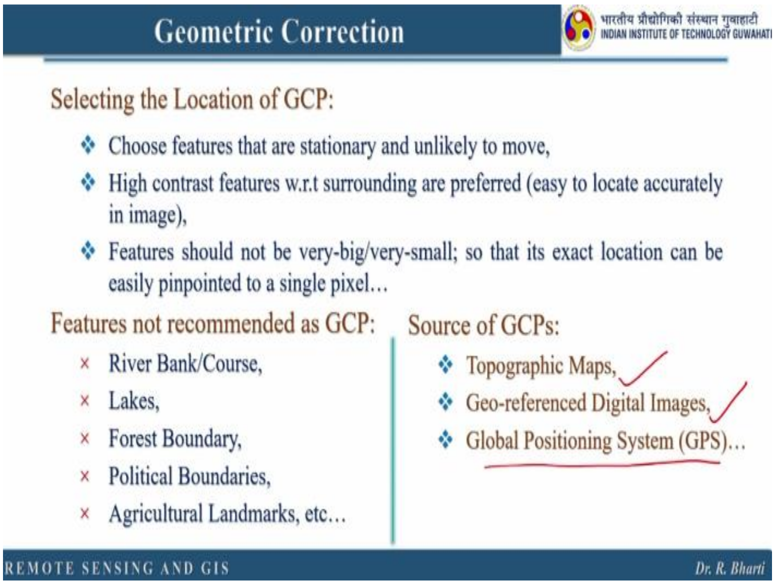

Like choose features that are stationary and unlikely to move, so in that case you need to find out some objects which are not going to move with respect to time. High contrast feature like those features, which are easily identified on your image that should be used. Features should not be very big or very small why because; if it is very big then the whole image will be covered by that particular object only.

But if it is very small again, it should be able to identified in multiples of pixels then only you will be able to find out the corners like here if you see this one, so this particular corner can be identified and this particular corner can be identified. But if you use something like here, this is a tributary which is coming here, so if this point you want to correlate with the map or with the ground, it is very difficult where you will consider and whether that is correct or not? Who will say? So you need to take care of this GCP selection.

And the features should not be considered, they are listed here. So you can see riverbank course, lakes, forest boundary, political boundaries, agriculture landmarks, some sources from where you can collect this GCP. So first thing is topographic map you have seen already that if you have a toposheet where each pixel is having X, Y and Z value that can be considered in this source of this GCP, second is you have already a corrected satellite image that also can be used as a source of GCP.

And third one is GPS, so here with a GPS you can go to the field and you can pinpoint a location which can be easily identified on your image and then measure the latitude/longitude value note down the class value that means whether it is forest or whether it is an urban area or whether it is a rural area.

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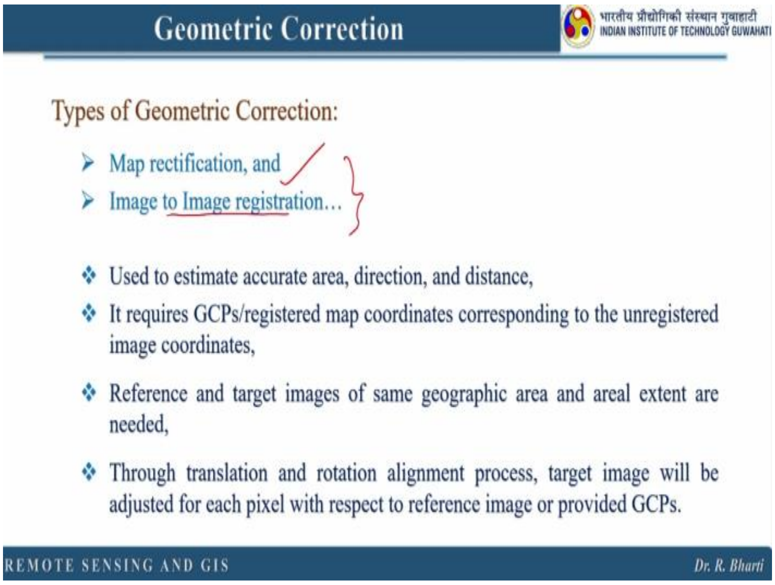

Now, we will see types of geometric correction. So first one is map rectification: so when you have generated a map with your pen and pencil and then you have measured the corner latitude, longitude value and this is the case when you have toposheet. So what we do? We have to scan this, you have to bring it into digital format, then using these locations you can convert this whole image into geometrically corrected toposheet.

Next one is image to image registration, so in that case considering you have a map available with you and you have a satellite data measured today, then you have to use some points which are stationary in time and then correlate them and then correct this image, so after correction, this may look like this. So this geometric correction is basically used to estimate accurate area direction and distance. Now, you have understood this, it requires GCP or registered map coordinate corresponding to the unregistered image coordinates.

Reference and target image of geographic area and aerial extent are needed through translation and rotation alignment process, target image will be adjusted for each pixel with respect to reference image or provided GCP. So here basically what I want to highlight that there are 2 types of correction in the first case, you do not have any source map you have only map or satellite image you want to correct with respect to GCP.

So in this case only GCP can help you. So GCP is ground control point measured in the field. Now in this case the GCP source can be your map or the earlier corrected satellite images and in the both the cases you have to find a common feature on both map and images and then you have to use the correct latitude, longitude value and the target latitude, longitude value. So then accordingly you will build a relationship and then you will correct them, that we will see in detail.

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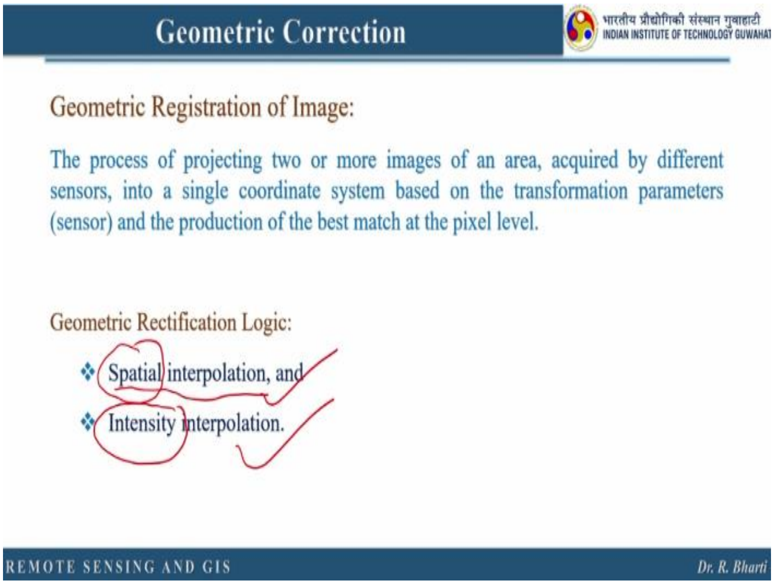

Now in geometric registration of image: The process of projecting 2 or more images of an area acquired by different sensor into a single coordinate system based on the transformation parameters, and that parameters will be from sensor and the production of the best match at the pixel level. So there should not be any change between this map and the image which is acquired by sensor after the correction. So there are 2 logics.

This is how we are going to correct our image. So first one is spatial interpolation and the second is intensity interpolation. So as the name indicate spatial interpolation, so spatial is basically it is related to location. So latitude, longitude where, whereas this intensity is related to DN number how you are going to extract this value, the real value of the object from the old to the new one, new one is your corrected image, so how you are going to assign these values?

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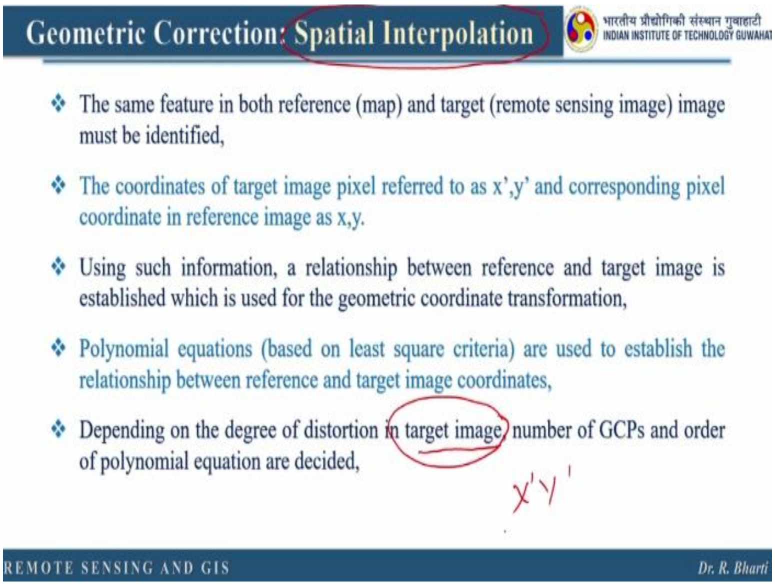

So in spatial interpolation, you can see here. So the same feature in both reference and target image must be identified, here the coordinates of target image pixel referred to x dash y dash and corresponding pixel coordinate in reference image as x, y. Using such information our relationship between reference and target image is established, which is used for geometric coordinate transformation.

So polynomial equations are used to establish the relationship between reference and target image coordinate, depending upon the degree of distortion in the target image number of GCPs and order of polynomial equation are decided. So target image, I am referring the satellite image which is captured and which has to be corrected not the map, map is our source of this GCP, so here basically this is going to be your x dash y dash and the GCP will be x and y.

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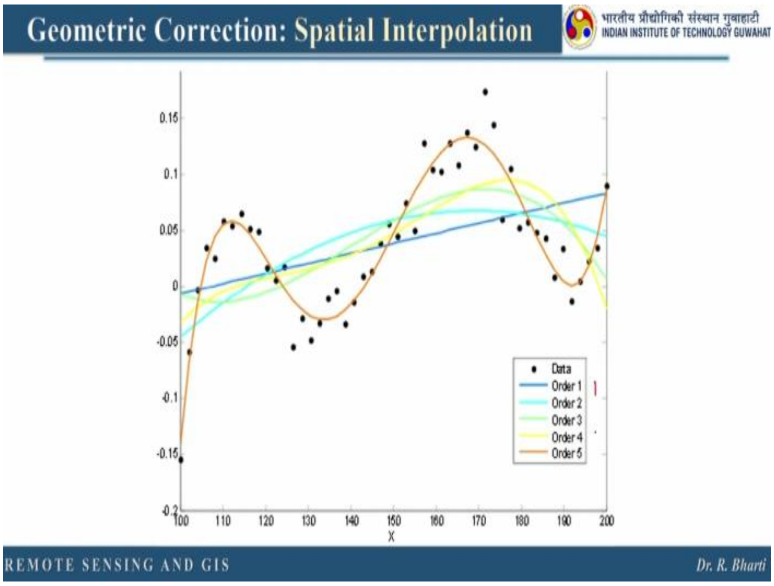

If someone is having linear relationship, then you can use first order, second order, but if it is not linear, then you have to increase your order of polynomial equation.

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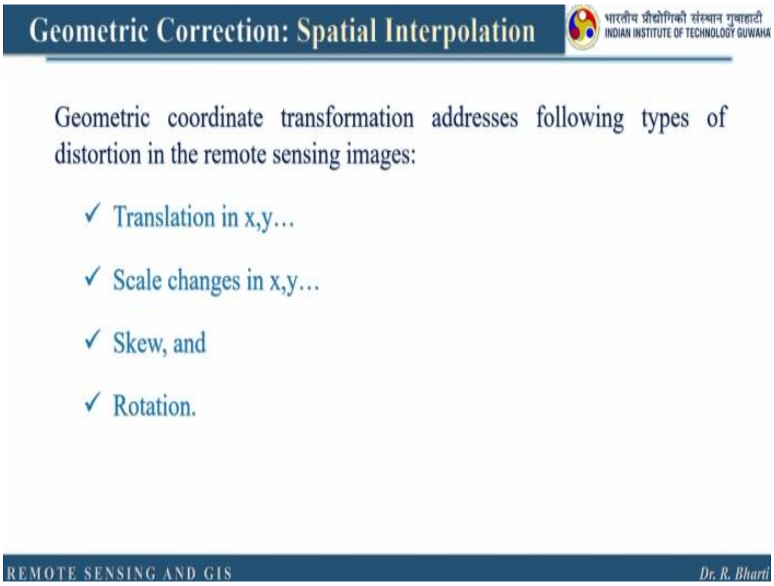

So geometric coordinate transformation addresses following types of distortion in the remote sensing image, like translation, scale changes, skew and rotation will see how it is going to affect your pixels and after correction how it will appear.

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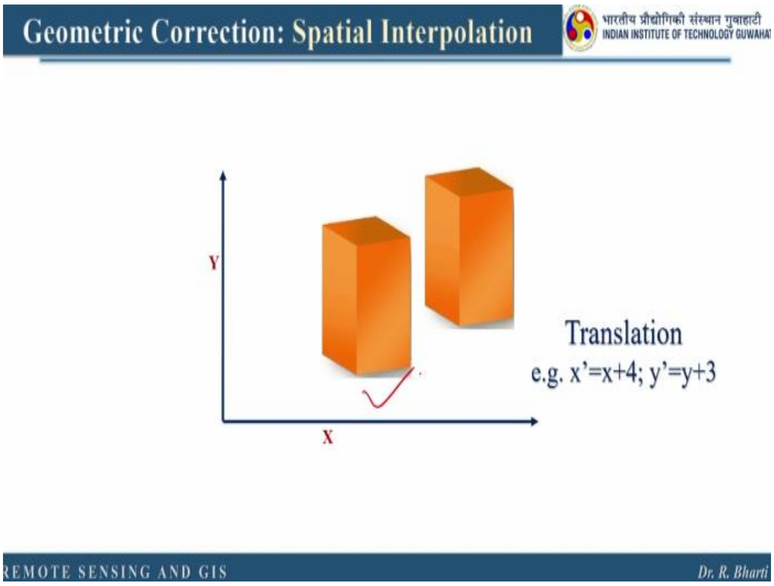

So in translation, basically, this was supposed to be like this but it has shifted.

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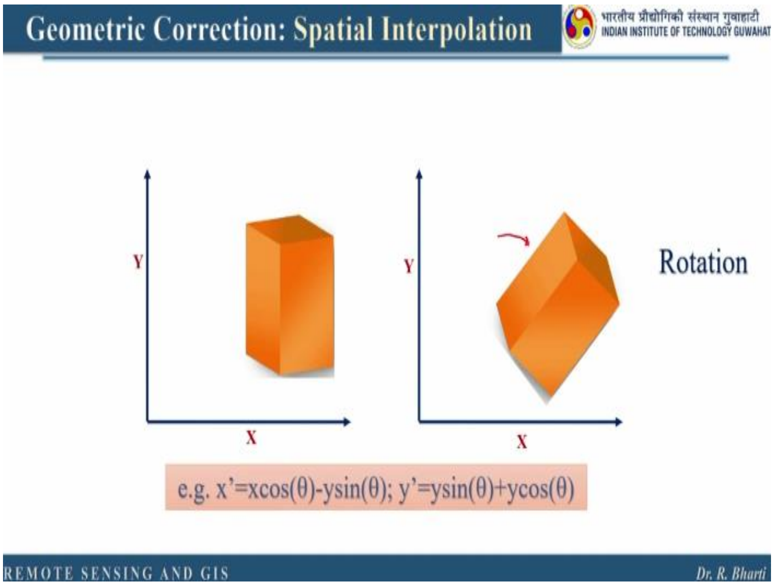

Now in case of rotation what will happen? It will rotate with some angel.

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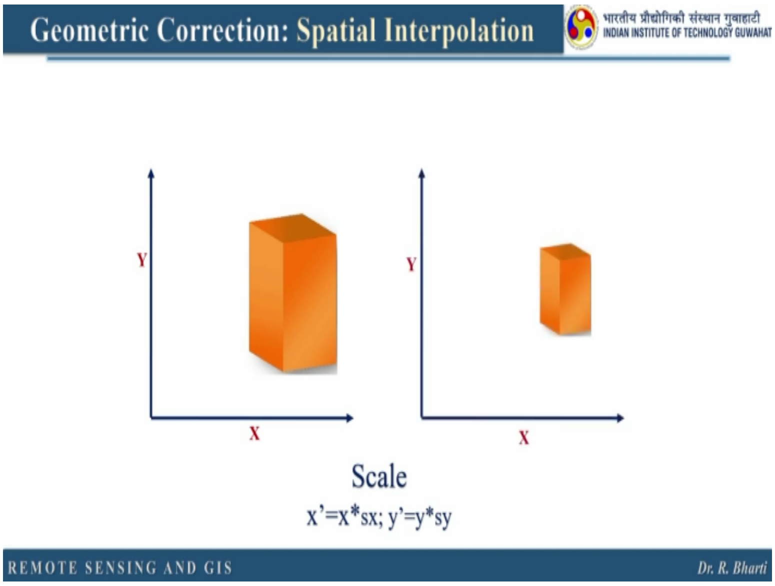

So in case of scale there will be change in the size, so this is the effect.

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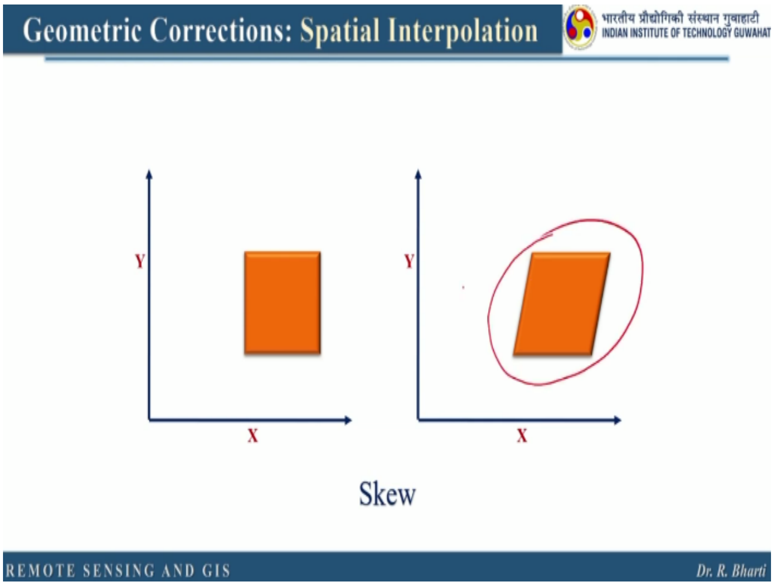

So in skewness because of the earth also we have seen so there will be change in the orientation. So you need to understand how these are going to affect your image and after correction it has to be in it is proper shape, size and location.

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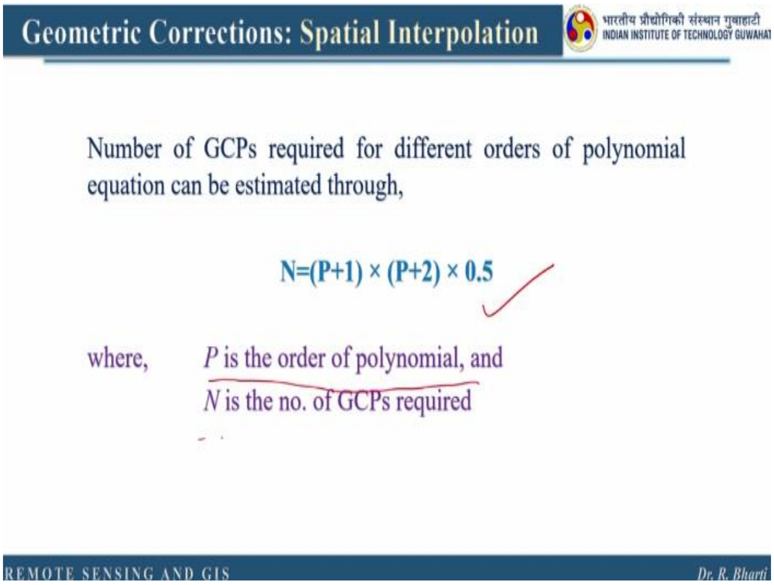

So the number of GCPs is required for different orders of polynomial equation can be estimated using this equation. So you can see P is the order of polynomial and N is the number of GCP required.

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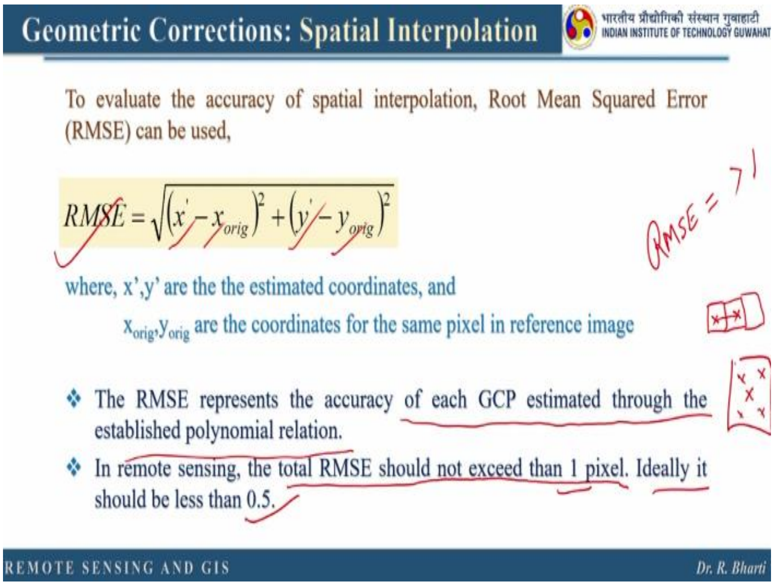

To evaluate the accuracy of spatial interpolation RMSE can be used. So, the RMSE represents the accuracy of each GCP estimated through the established polynomial relation. So, what is the predicted or calculated one for the target image? So, in that case, you need to find out what is the RMSE and in remote sensing the total RMSE should not exceed than 1 pixel, that means RMSE value should not be more than 1.

And why so, because 1 means here we consider these pixels if RMSE is more than 1 that means this object with which was supposed to be here it will get shifted to another pixel, so it is a thumb rule that it should be less than 1 and ideally it should be less than 0.5. So that means if it is 0.5 that means the object which was supposed to be in the center, but because of some errors it got shifted to this or this location, but at least that will remain within that particular location. So that is the advantage when you are having this RMSE less than 1.

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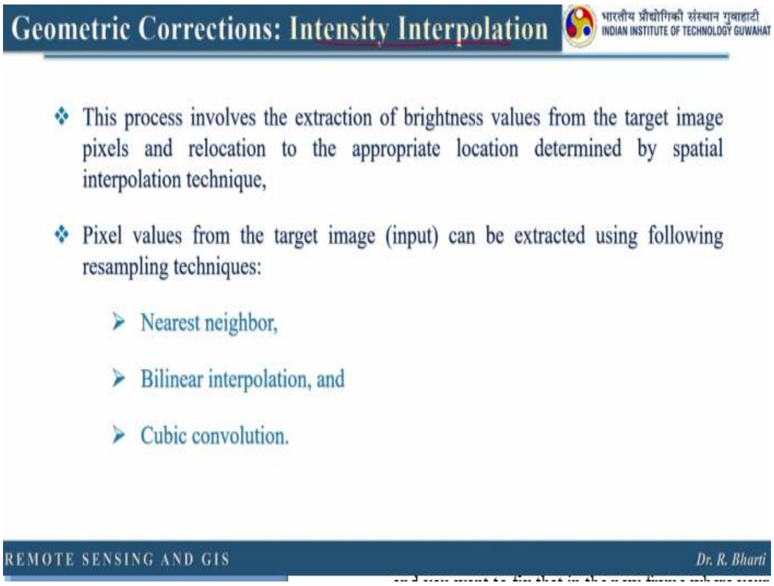

So now we will see the intensity Interpolation: here, this process involves the extraction of brightness value from the target image pixel and relocation to the appropriate location determined by spatial interpolation technique. So basically, here what you are going to do, you are going to extract the values of those pixels from the raw data and you are going to take that and you want to fix that in the new frame where your locations are correct.

So how you are going to do? There are some logics we used to use here, pixel values from the target image can be extracted using following resampling techniques, so first one is nearest neighborhood, then bilinear interpolation, third one is cubic convolution.

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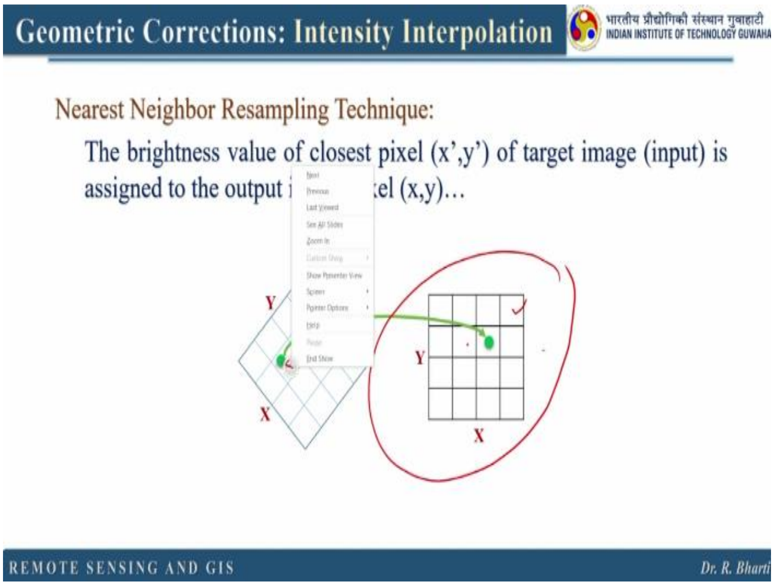

So in nearest neighbor resampling technique: The brightness value of the closest pixel of the target image, target image is basically your input image is assigned to the output image pixel. So output image pixel is basically the orientation of your pixel identified by your spatial interpolation technique. So here you can see this is your input and this is your output now here this output is basically the location of these pixels, have been corrected using this spatial interpolation technique.

Now, you want to extract these DN values and you want to locate it into your final image. So how we will do that? We will take that and we will plot it here, so in nearest neighbor, whatever is near to this that value will be taken.

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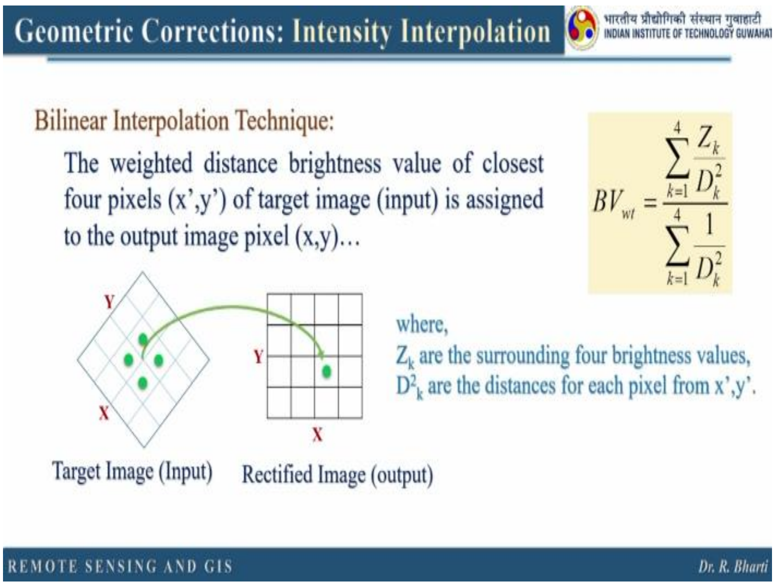

In case of bilinear interpolation technique: the weighted distance brightness value of closest 4 pixel of target image is assigned to the output image pixel, so this is very simple here, you will consider 4 pixel and the weighted distance brightness value will be assigned to this particular pixel.

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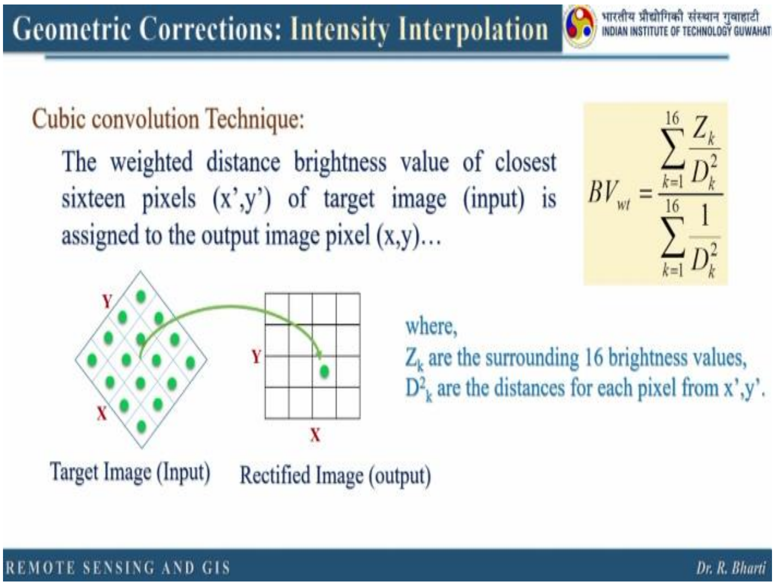

In cubic convolution: What is happening? You will be using 16 adjacent pixel and those will be averaged and that will be assigned to this. So, this is how we are going to do intensity interpolation. But if you see in the first case like in nearest neighbor what happens we have not done any averaging so and ultimately why we are using this remote sensing data to derive some information.

So, I will suggest that if you are going to use this for any quantitative analysis, then you are supposed to use nearest neighbor interpolation method.

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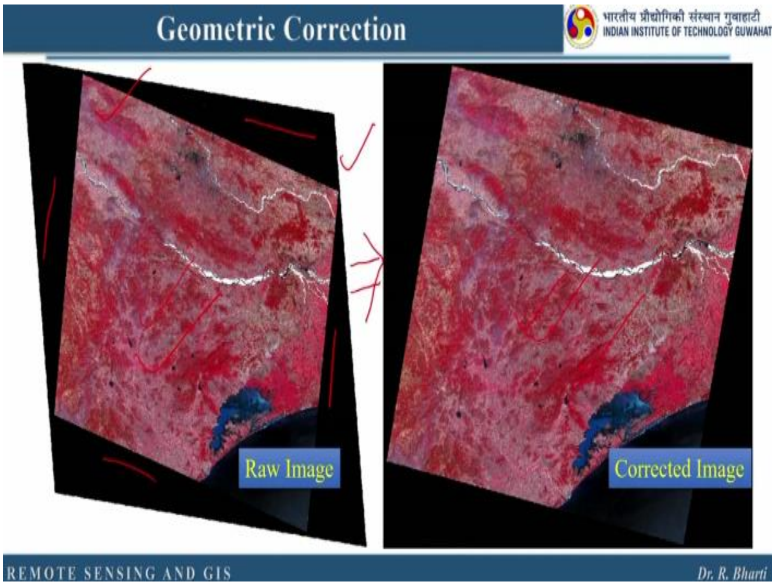

This is one image captured by a satellite X and initially the orientation of this image, you can see how it is appearing, but when you do the geometric correction, the all pixels are into their own position. That is all for today. Thank you.