Digital Elevation Models and Applications

Dr. Arun K. Saraf
Department of Earth Sciences
Indian Institute of Technology, Roorkee

Lecture – 02
Various Techniques to Generate Digital Elevation Models – 1

Hello everyone and welcome to the second lecture of a digital elevation models and application course, in this particular lecture we will be discussing various techniques to generate digital elevation models. So, there are going to be three lectures on this topic, but a in different lectures, we will be saying different techniques to generate digital elevation models. In this particular one we will be discussing a one a technique which is based on the interpolations, the earlier it was one of the most popular technique, and is still many people are using depending on the data which they are using going to use depending on the project, accordingly we choose the appropriate technique to generate digital elevation models.

A as we know that they and digital elevation models can be created a through number of a ways different techniques are there, but a most preferred one is the method of generating dm in the remote sensing base. So, these are the these are the ways of we can create digital elevation models, the earlier we used to have survey deposits like survey of India topographical maps using contours our point heights, we first used to digitize and assigning that elevation values to these point heights or contours as a tribute value, and then using these values we used to create a surfaces which are estimations of values through spatial interpolation technique.

So, this is one of the popular one is a is spatial interpolation technique in this particular lecture we are going to discuss in detail about how different interpolation techniques can be (Refer Time: 02:19) to generate digital elevation models, what are the limitations accuracy issues, and some other applications, other way of creating digital elevation model by using stereo pairs and like a might be available from a spot our own Indian satellite like, cartosat etcetera which is nothing, but a remote sensing method and that too based on photogrammetric technique, this is also popular this will be also discussing in subsequent lectures.

There is also one technique a few years back I have developed which is based on thermal.

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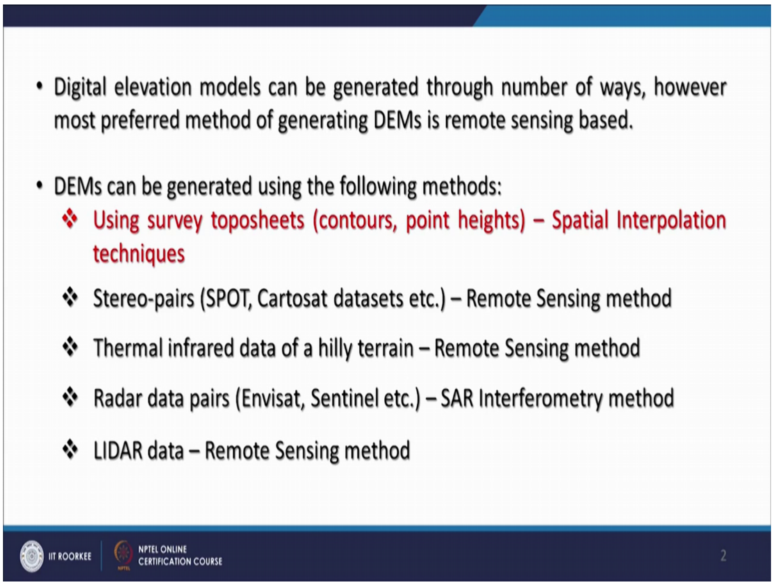

Infrared of a hilly terrain, but at a relatively low resolution, but a this is this can give you some advantages as well. So, that will be also discussing in brief a in and subsequent lectures, then radar data pairs many very popular technique nowadays, either you can use a for example, and Envisat data and or sentinel data, which is still operational sentinel and employing this in sorrow intromit interferometric method.

One example in previous lecture we have seen about the srtm, srtm digital elevation model for eighty percent of the globe was generated using this insar technique, which is purely a remote sensing base technique. Now lidar data again is a remote sensing method, but the most popular one and nowadays based on either on aircrafts or on ground based lidars can also be used, and to a create surface a models and so that we will be also discussing very briefly.

So, let us first a come to this a spatial interpolation technique using either contour data or point heights. As you know that contours are representing the equal heights or iso height, I tell contours we say them and they if you if you see from vector data structure point of view, then these are the polylines and polylines are having in between various nodes, including two end nodes and begin node and the end node, and in between various internodes are there and these nodes are assigned elevation values and they make basically a contour line.

So, contour line is also made from points and they of course, a point heights can also be used to create a digital elevation models using a spatial interpolation techniques, various software's will use a directly and through a point side you can create a surfaces that is the digital elevation model through interpolation, or a some software's will also allow you to create a dms using contours, but what a what these software will do in the background first they convert your polygon or polylines to point because, these polylines are also made from point and then create the spatial interpolation.

So, why because for is inter interpolation the data has to be supplied in the form of point data only. So, line or polyline can be converted to point first, and then can be used to create surfaces. And basically, the concept of this a spatial interpolation is based on a sort of belief, and belief is that the day if you are having to observation points and a in for between in between you do not have any observation, but if you believe that they are linearly related or non-linearly related then a value can be estimated between two observations.

So, using this belief depending on the terrain conditions, one can create a surface. So, from point data which is a discrete data vector data a continuous data or raster data can be created which is nothing, but a digital elevation model. So, spatial interpolation techniques basically converts your raw data into a useful information, because once surface is created a digital elevation model is created, then various a various products can be generated as mentioned also, that a dm digital elevation model is a storehouse of information, various types of information's can be extracted a from digital elevation model, and models which we will be seeing in subsequent discussions.

So, by adding this a greater informative content and value, instead of just using point data which may not give you that kind of that level of information as a surface or a digital elevation model can provide, also when we convert this point data into surface; that means, from discrete to continuous we can also see different patterns which are present in your four in your surface, and like a example earlier also shown that in a digital elevation model can tell you where which are the areas which are having the ridges or a hilltops, which are the areas having valleys or and you know drainage lines.

So, these patterns can be revealed using digital elevation model or using surfaces rather than using discrete data that is point data, also we can see the trends in the data anomalies might be a you know suddenly you are having held, a or may be rich or may be a depression those things can also be anomalies can also be seen otherwise in this simple point data plotting, you may miss all these things, and also it provides a check to human intuition because a between two points as given.

The example if you do not have any information then there are techniques to fill that information to estimate the value and therefore, instead of using a human intuitions we used the mathematical algorithms and to estimate the values, and a these can be also checked later on implying by differential elevation, differential GPS, or some other elevation models and then can be compared may be a low spatial resolution digital elevation model, and using random pointer we can compare and see that how close they are with the reality.

So, it a really in that way very useful by helping in situation where I might a deceive where we may not a see in a typical, this is the typical flow process or a you know flow diagram of the processes which are involved, in a while creating a digital elevation model using topographic maps, the first step in topographic maps if they are not already available in digital form nowadays a lot of a.

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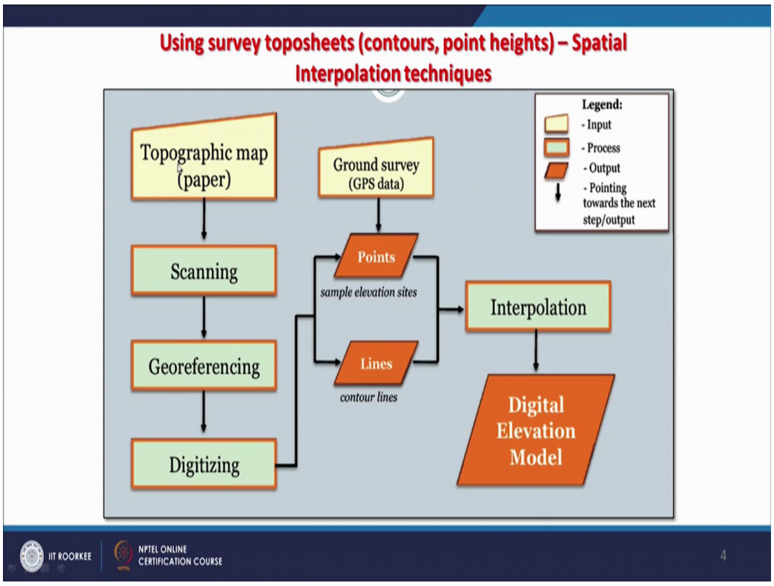

Topographic maps are also available in digital form. So, what we need basically we need the contours or point heights extracted from those topographic models, a and topographic maps if they are already not if they are not available then the first step is going to be the scanning using a flatbed scanner or some roller scanners, then we do the geo referencing; that means, a bringing the geographic coordinates into your scanned a image, because that map or a scanned a image of a map will be in a geometric coordinate. So, by implying geo referencing technique which has been discussed in length in detail in the gis course.

So, that can be used here, and then we can digitize individual contour lines point heights, and then we get these two outputs points or lines as I have already told you that directly from lines, most of the software's especially gis software will not allow you to do the interpolations. So, lines can be converted into points and you can also bring a GPS data, especially the differential GPS data for verification or validation of your interpolations. So, that is also there finally, you can create the interpolations, and this dgps data can also directly the data can come as a in point forms, and that data can be used to create digital elevation models through spatial interpolation techniques.

So, this is how the entire process of a creating digital elevation models employing spatial interpolation techniques using topographic maps. This this a this was a very popular before we got this digital elevation models globally, specially I am talking like srtm or aster gdem. Now as we can see here that these are the contours.

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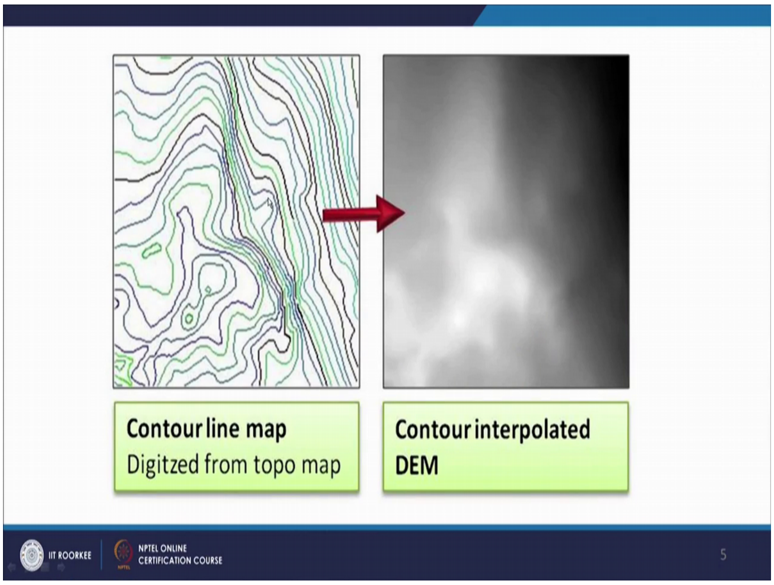

represented and the same contours can be used to create a surface that is nothing, but a digital elevation model, and this is how it will look.

Now, as mentioned here that a the surface or dm will reveal the patterns. So, here we can see some patterns and some anomalies and other things can be seen quite easily as compared to contours, now in a spatial interpolation. So, first we will look the definition then various types of spatial interpolation techniques, and then some limitations accuracy issues and other things. So, let us see first what is how we can define the spatial interpolation, which is a procedure of estimating the value of properties.

Now, property here may be elevation may be concentration of sometime chemicals or may be water level and so on at unsample sites because for that we do not have the observation, this is key point why we are doing interpolation, because we are doing interpolation because for all points we do not have the observation, and a observations are not available at regular intervals observations are available at irregular intervals and therefore, we want to create a systematic surface where each cell will represent a certain value may be elevation value.

So, that is why the spatial interpolation is the procedure of estimating the value of properties, at unsample sides within the area covered by existing observations. So, of course, and this interpolation also includes some extrapolation as well beyond the area, but there the errors will be very high. So, one that is why in the definition it has been mentioned within the area covered by existing observations, if you do not have the observation and a still you go for interpolation. In fact, that will be called at extrapolation, and extrapolation can bring lot of errors in the data, but sometimes for the margin or boundary areas we also go for extrapolation which we will see in the demonstration while using a software.

Now, what basically interpolation is doing it is predicting the value, for a cell of a raster or a DEM from a limited number of sample data points. So, you are having some points which are randomly distributed in a space or in a given area, now using these points it is predicting the values based on different interpolation techniques at a regular interval. So, that it will fill the elevation values for each cell of a grid, because otherwise you do not have the data at a regular interval, and it can be used to predict unknown values for any geographic point data such as elevation rainfall chemical concentration noise levels and so on.

So, the elevation instead of elevation value you can have various types of value, and that is why the concept of digital elevation model is very popular and highly useful as well, now rational behind the spatial interpolation is the observation that points close to you close together in a space, are more likely to have similar values then point far apart, and this is based on the toblers law of geography. And they also we know in our day to day life that the a we will have more influence of those things which are close to us, we will have less influence of those values which are very far from us, and so, that is the toblers law of geography that the points close together in space are more likely to have similar values than those points far apart.

So, when we go for interpolations all interpolation techniques will avoid this a and toblers law of geography, by in a getting more influence of neighboring points then for distance point.

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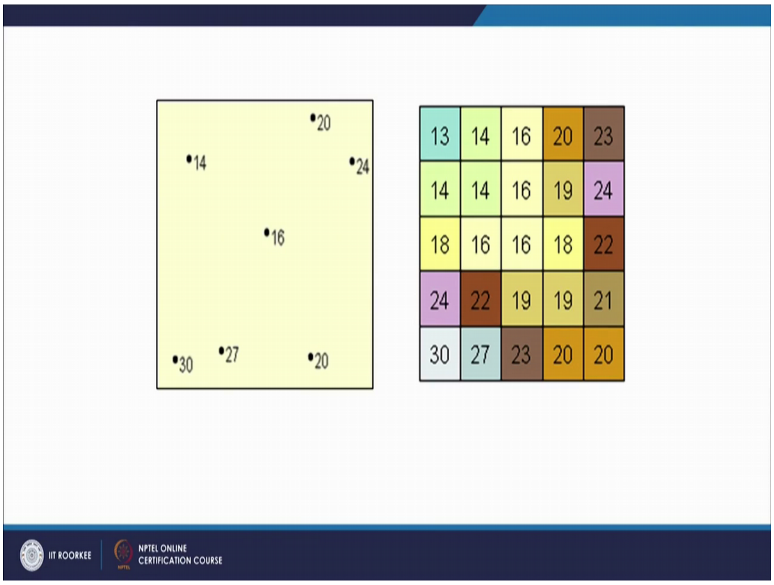

This is the example here that randomly distributed some elevation points are here, using these points a regular grid or a digital elevation model can be created, these lines say or this grid of lines and rows and columns are just shown for our understanding, but in a real digital elevation model boundary of each cell or boundary of entire dm, is not a really there except just for our understanding this grid of or biomass has been used here for our end.

But after interpolation what has happened, that each for each cell now we are having elevation values, and therefore, we say this is the discrete data set and this is the continuous data set, because at every location we are having some elevation value in the in the vector data or the point data set we do not have, and once we are having a values for each cell in a grid, then patterns anomalies and other things can be revealed, more real example here is that the randomly distributed points are here and then a surface has been created here.

If you recall the definition we said within the observation points, and here the observation points are marked by this rectangular area.

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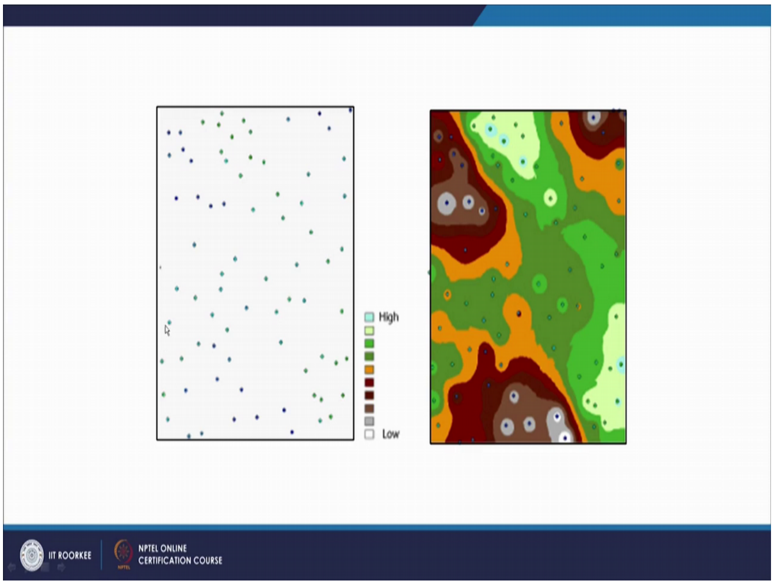

So, within this point the interpolation is done, but a if there are no observations here like especially here still the interpolation is done, but that is because on the other side we do not have any observation. So, for this area basically it is extrapolation. So, when we do the interpolation, though we call as interpolation what is a mixed and a as also mentioned that the at the boundary areas on the edges of our observation or edges of our output dm, we are also having extrapolation, and this this is this information is useful when we go for a areas which are having arbitrary boundaries, there we have to take some care about this extrapolation and interpolation.

So, in subsequent lectures these intricacies will come and we will discuss. Now a what basically a these surfaces are that a the these are a different interpolation techniques which we employ, and the differences in methods used for these a surfaces, are a represented a here or we will be discussing that each representation is useful in a specific situation.

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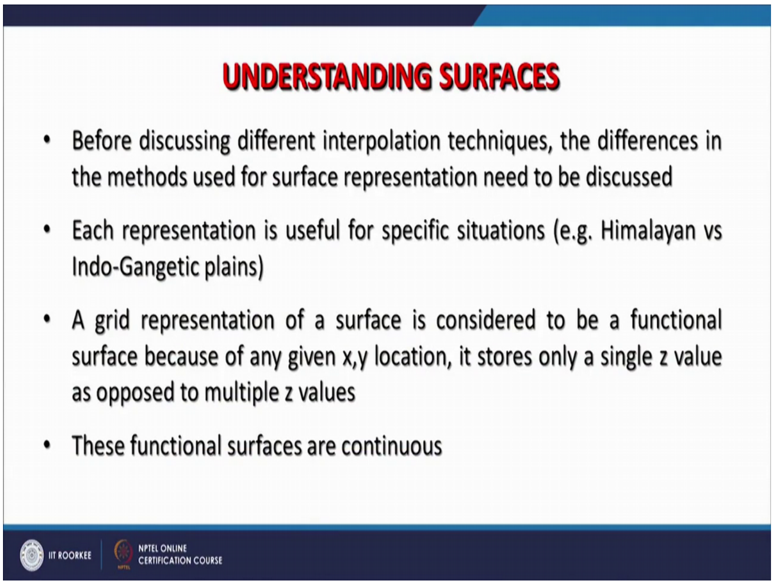

That means, one interpolation technique all our spatial interpolation technique. So, one interpolation technique may be useful for a terrain like Himalaya which is highly rugged a terrain, or the same technique same interpolation technique may not be useful for in do gangetic plains, which is a almost a plain area where you smoothly undulating terrain, if at all there are changes in elevation.

So, two extreme terrains are there same interpolation techniques cannot be employed, what I am trying to say that, if I am having point observations for Himalaya terrain what I am having point observations also for in do part of in do gigantic plain, I cannot imply the same interpolation techniques to generate digital elevation models, because a they because the terrain characteristics are completely different and therefore, the prior knowledge about the terrain about the data set has to be there, to choose appropriately a interpolation technique.

Later also we will be discussing, how to check or how to find out that which interpolation will suite my dataset as well. So, that we will see little later, but the here this is very, very important that depending on the terrain conditions, we have to choose appropriate interpolation technique, and grid representation that is through the dm the surface is considered to be a functional surface because of any given xy location, it is stores only a single z value as opposed to multiple z value.

So, the attribute of a digital elevation model is only one, and that can be in case of a typical digital elevation model that can be elevation value in other cases may be a water level value, or a water table value or can be a concentration of chemical quantities, and these functional surfaces are continuous as we know this one, now functional surfaces can be used to represent terrestrial surfaces that depicts the earth surface.

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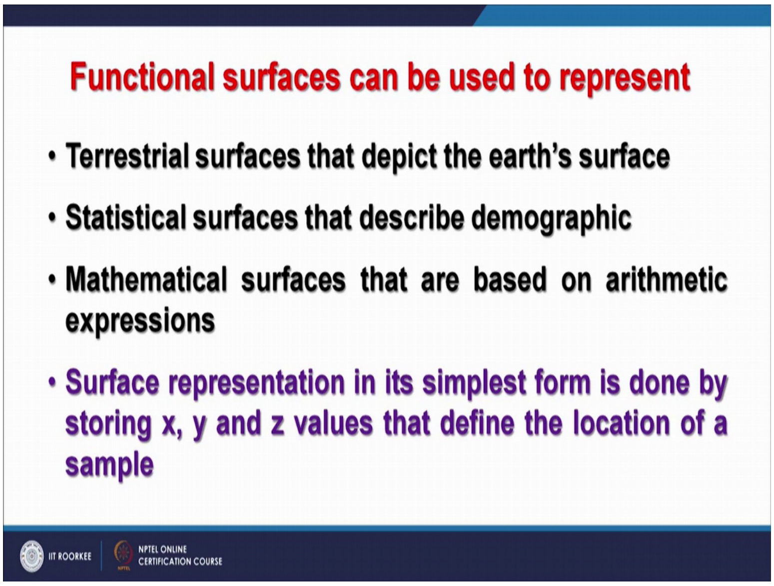

May be moon surface mars surface, because for these a areas or for a planet, like mars or a satellite of earth like moon and these digital elevation models have been generated, or also these functional surfaces can also represent statistical surfaces, which describe the demographic and mathematical surfaces that are used on arithmetic expressions.

So, various techniques are there the surface representation in it is simplest form is done by storing x y z values, that defines the location of a sample and this is a typical digital elevation model, in case of contour line representing elevation, it is a line drawn on a map that connects points of equal elevation and our (Refer Time: 22:17) that is usually represents our (Refer Time: 22:19) level.

So, a this is what we get a through the these topographic maps, that contours lines are there, which are represented the iso heights and these points can be used to create surfaces. So, in from discrete we get the continuous data, also we can create using these points a TIN surface that is more close to vector data structure, and a which can store and display surface models that we will be also seeing in this course and TIN basically.

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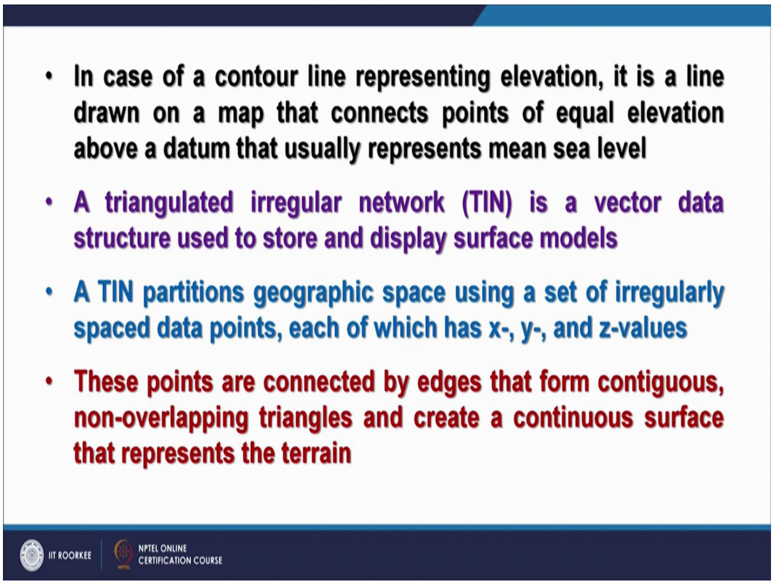

What it does it partitions the geographic space the given area, for which you are having the point observations .

Using a irregularly spaced data points each of which x y and z values in like in a typical digital elevation model, but here instead of having a square unit, here the unit is triangle and this the size of each triangle going to be different whereas, in case of typical grid based dm the size of all a cells is going to be the same. So, this is major difference here. So, these points are connected by edges in case of TIN that form the contiguous non-overlapping triangles and create a continuous surface that represents the terrain.

So, terrain can be represented earlier we used to have simple contours, which also is a way of representing topography, but it is discrete terrain can also be represented through the interpolated surface using point heights or contour values, through interpolation we can create or (Refer Time: 24:09) as well. So, there are various methods of representing terrain the undulations ruggedness of the terrain can be represented by all these models.

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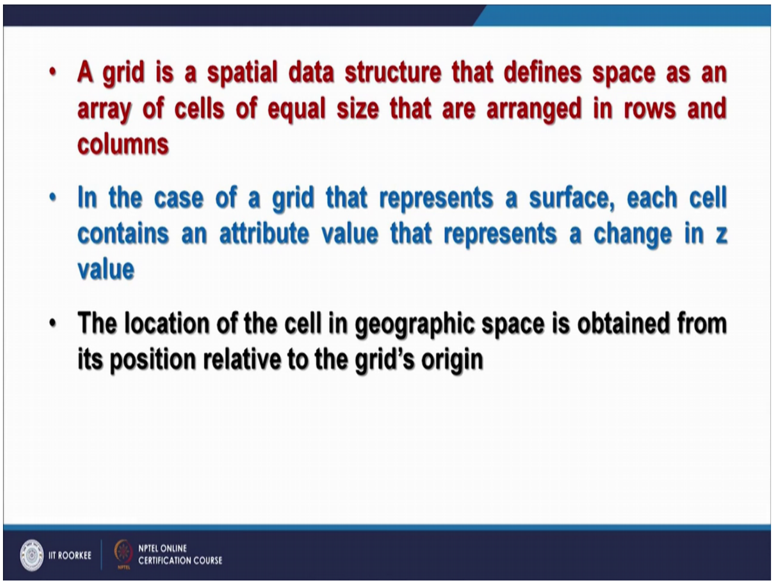

Last the grid is a spatial data structure we know, that defines the space in an area of cells of equal size that are arranged in rows and columns, remember this that each cell is equal within a data set, if it is representing five meter by five-meter ground area, then all the cells will be representing five meter by five-meter area whereas, in case of ten all triangles can be representing different sizes of areas. So, that is why it is irregular triangles, it is no regular triangles are there, but in case of cells all are having equal size.

In case of grid that represents a surface, each cell contains an attribute value and raster will always have one single attribute value whereas, in vector as we have learned in gis course can have n number of at the theoretically n number of attribute value, but raster will have only one attribute value and generally we assign z value, now this z value depending on our requirements can be elevation value concentration value depth value or any other thing, and a this a the location of cell in geographic space is obtained from it is position relative to the grids origin.

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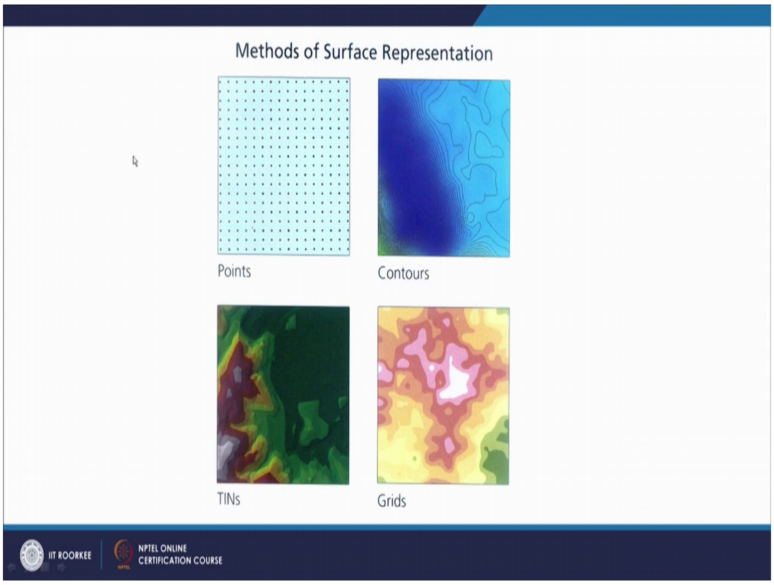

This is the one example here that a here we are having points data though it is given at a regular interval whereas, we can create a contours using point data through again interpolations, also we can create using the same point data a grid that is a typical digital elevation model, or using the same point data we can also create TINs. So, three products which we are seeing immediately using point data through interpolations one is contours, another one is a surface that is digital illusion model, and third one is a TIN, TIN is also surface, but the data structure is entirely different then typical raster dm.

Now, the question is a why to interpolate, because it is not possible to visit each and every location in a study area. So, we go and for a sampled when we go for sampling or collecting ground information, it is not generally done systematically, wherever it the accessibility is there we collect that information, and a using that information later on throughinterpolation we can create a continuous information. So, a the study a the visiting every location in a steady area to measure the height.

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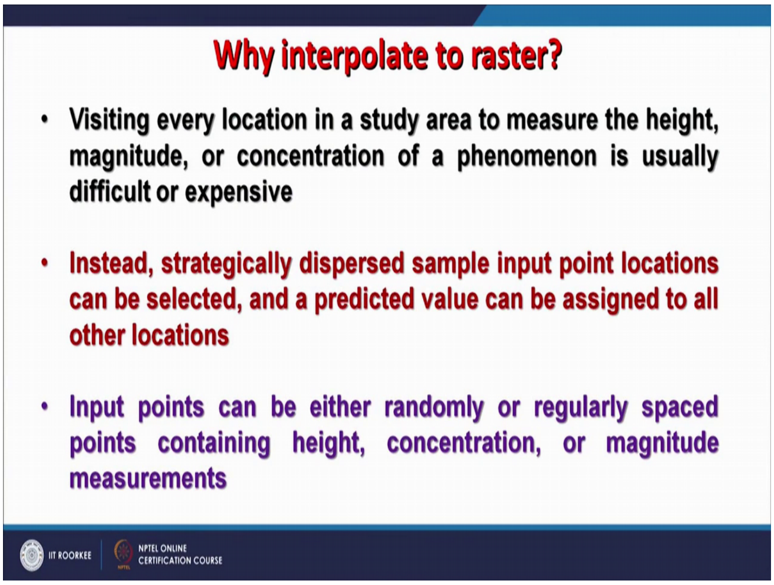

Magnitude or concentration of a phenomena is, usually difficult expensive or maybe in certain conditions impossible and therefore, we would like to have a certain technique to have information about those areas, which were not visited at all and that is only possible through spatial interpolation technique.

So, instead a strategically dispersed sample point, input point locations can be selected and a predicted value can be assigned to all other locations, and these are the estimated values remember these are not measured value, only we are putting measured values to create these estimated values. So, measured values are always there, but only for selected locations and a input points can be either randomly or regularly spaced points, containing heights concentration or magnitude measurements, and we continue on this that the as we have seen about the assumption, and the assumption is that makes the interpolation a viable option that spatially distributed.

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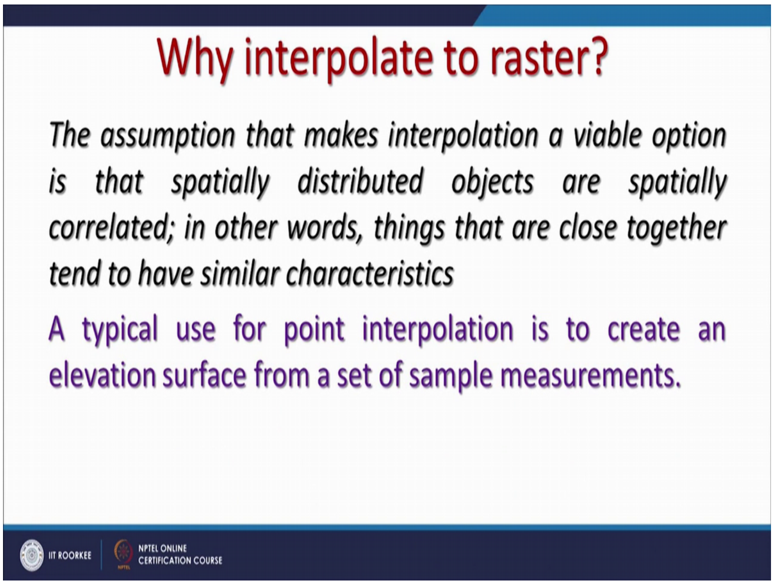

Objects are specially correlated, in other words we can say that things that are closer a toblers law of geography that the things that are closer together, tend to have similar characteristics and a typical use of point interpolation is to create an elevation surface from a set of sample measurements.

Two basic types of interpolation techniques which have been implemented in gis for creating a digital elevation models, which are based on mathematical functions.

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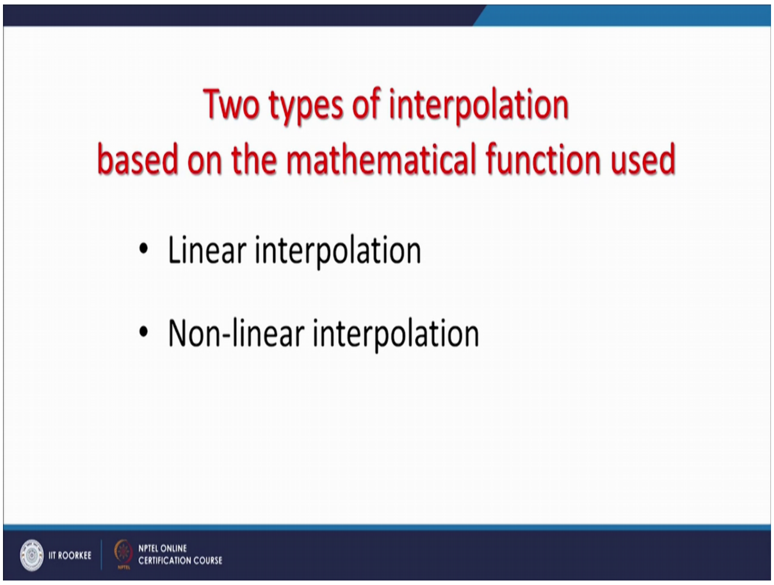

And one is a linear interpolation and of course, is the second one is non-linear. So, linear is little you know in that sense that a it predicts easily, but it has got limitations. So, people go for non-linear as well, now for example, in the case of linear interpolations if a for where the question mark is shown.

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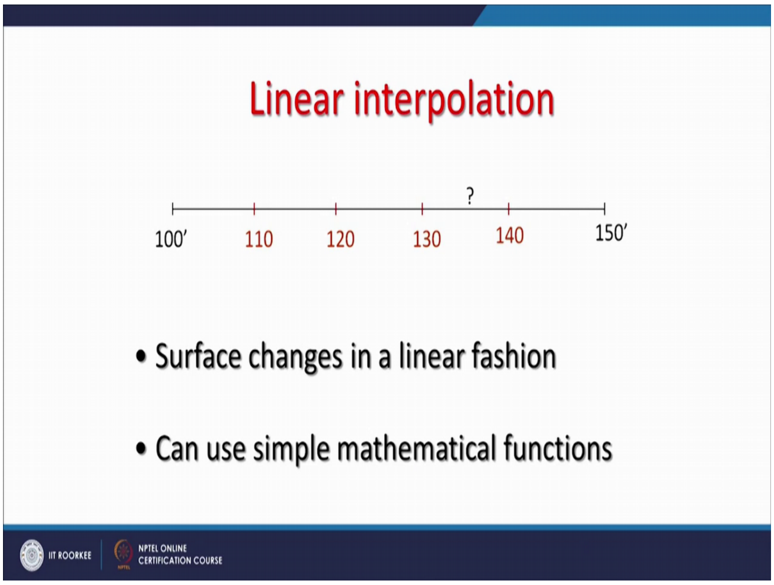

We do not have the information, but we are having two information's on each side.

So, it is then it becomes easier to estimate if this value at the center using the concept of linear and that things are linearly related, if we assume this thing then it becomes very easy to predict the value, that probably the value might be going to be 135, but if things are not related linearly then it is a different scenario and then we go for various types of non-linear techniques. So, surface changes in a linear fashion we know this thing can use simple mathematical functions while doing a linear interpolations.

There are some areas where linear interpolation is preferred over non-linear interpolation, which we will also touch upon this. So, point wise interpolation used for data which.

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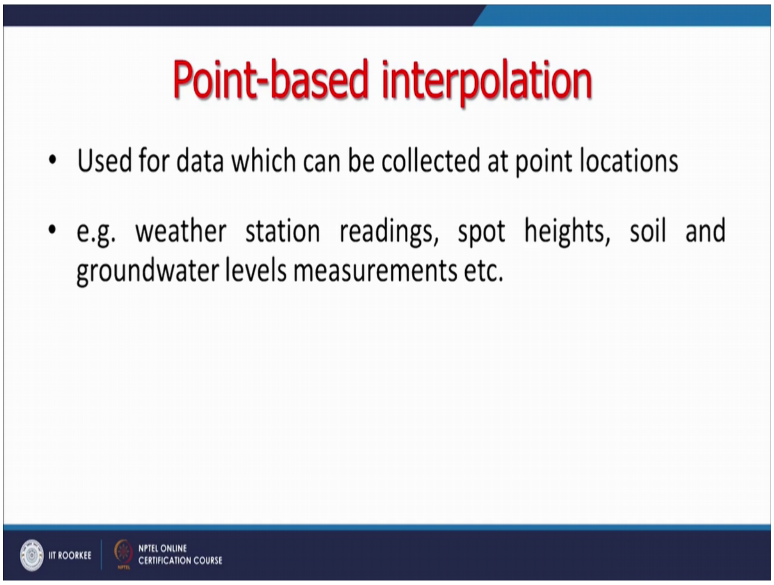

Can be collected at point locations and a for example, whether station readings for maybe rainfall data, maybe temperature data a spot heights soils groundwater levels measurement etcetera, all these can go here the example of a typical linear interpolation and technique is called thiessen polygons.

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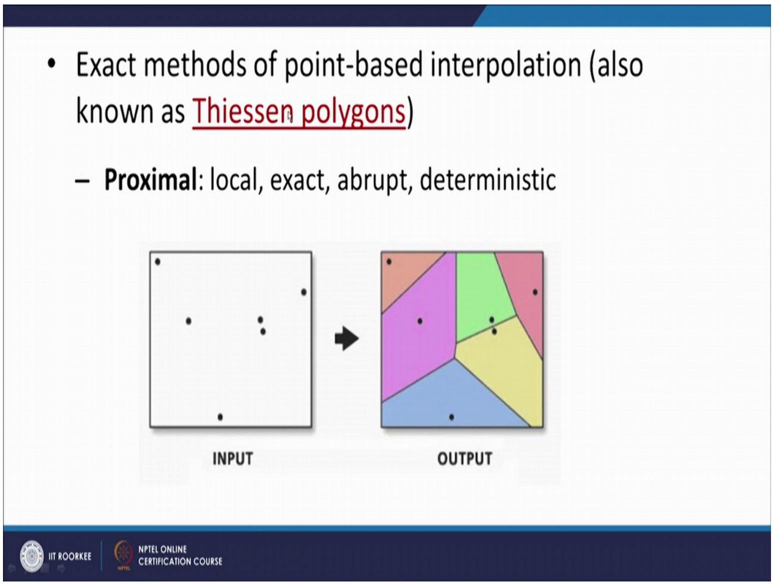

And this is called also exact methods which is input is point a points data are there, and we do the interpolations assuming things are really linearly related, that is through thiessen polygons concept it is a proximal local exact abrupt and deterministic.

So, all possible things are there one example here is this is the input data, and this is how these thiessen polygons are formed. So, in between like if I take the example here then at equal distance a line is drawn, again here between these two points at equal distance a line is drawn, again between these two points a equal distant line is drawn and likewise a complete polygon is formed, and there is a thiessen polygons matter then we did not have the very good non-spatial or non-linear interpolation techniques for rainfall data many people used to go for thiessen polygons.

So, within assuming that within one polygon, it is having the same rainfall value, but as we know in nature it is not a correct or always. So, a choosing a appropriate interpolation technique will depend on for which phenomena we are going to use it, and non-linear now again it is based on the toblers law of Geography.

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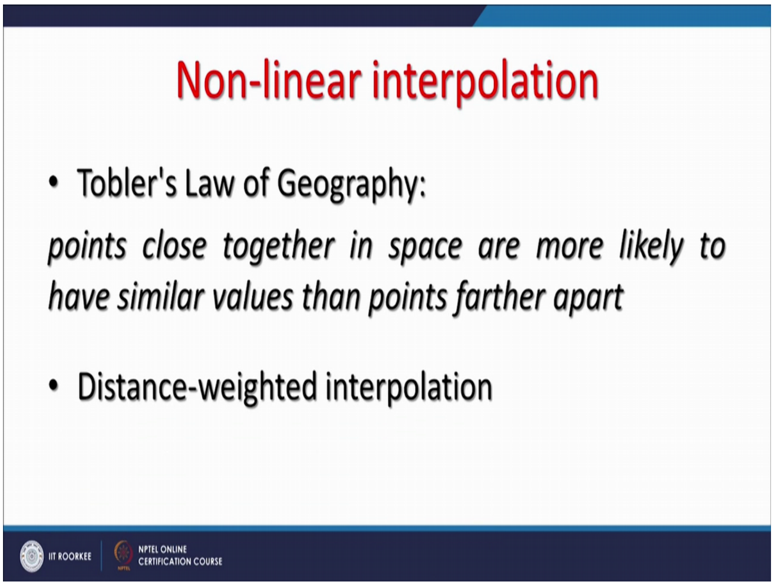

Points close together in space are more likely to have similar values than point further apart, and a we can also involve a technique which is called distance weighted interpolator or inverse distance.

So, a closer to the point will have more influence on the estimation, and points which are very far will have less influence. So, distance and the technique very popular one of the very popular non-linear interpolation technique is called inverse distance weighted IDW, it has been implemented in many gis software's and in which this estimates the cell value by averaging the values of sample data points in a neighborhood of each processing cell.

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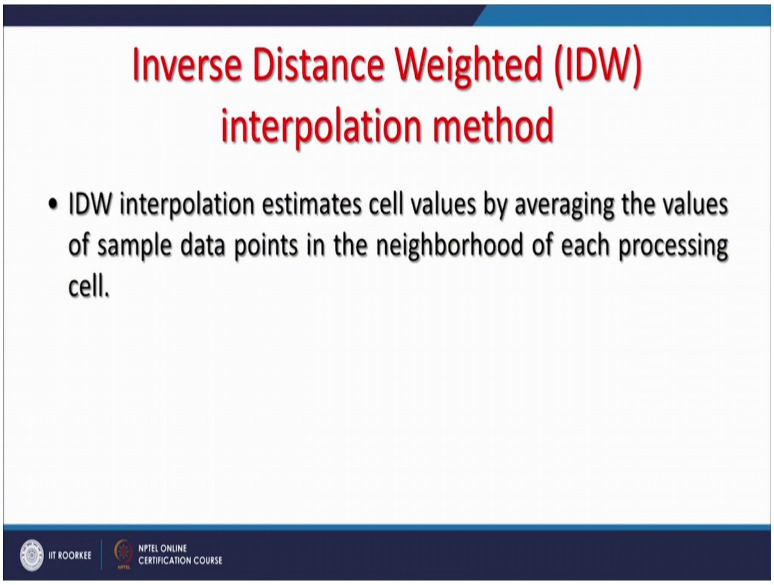

Now, this neighborhood can be decided either using a search radius or number of points in the vicinity, and those things can be you. So, closer a point is to the center of the cell being estimated more than influence, will have or weight it can be while averaging process, that is why it is called inverse distance weighted it is a weighted average based on the distance, less distance more weight more distance less weight that is why inverse word has been also been, this is the one example in IDW interpolation assumes that value is being mapped decreases and influence the distance from it is sample locations and for example, when interpolating a surface of pollution a more distance location will have less influence of a pollutant.

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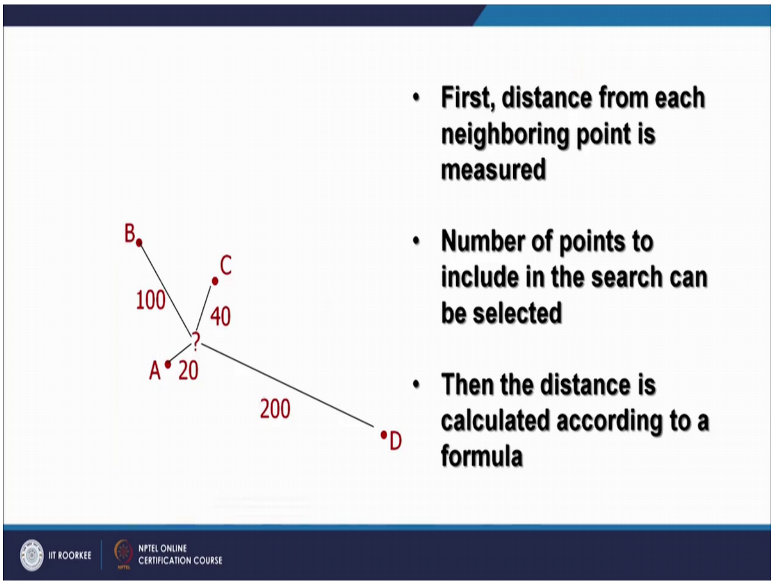

This is how it is a done and that a for a the area which is a location which is marked as a with the question mark, this will have maximum influence or more influence from point a which is having value 20, instead it will have and a it will have the least influence from point d which the value is 200 though the value is high, but the distance is more. So, in inverse distance less distance will have more influence on this value.

So, first the distance from each neighboring point is measured. So, for wherever the value has to be estimated, the distance from each neighboring point is measured and then number of points to include in the search can be selected, as I have said that the search can be either based on the points and also can be on the radius, the this I will demonstrate to you through a software as well later, and then the distance is calculated according to a formula.

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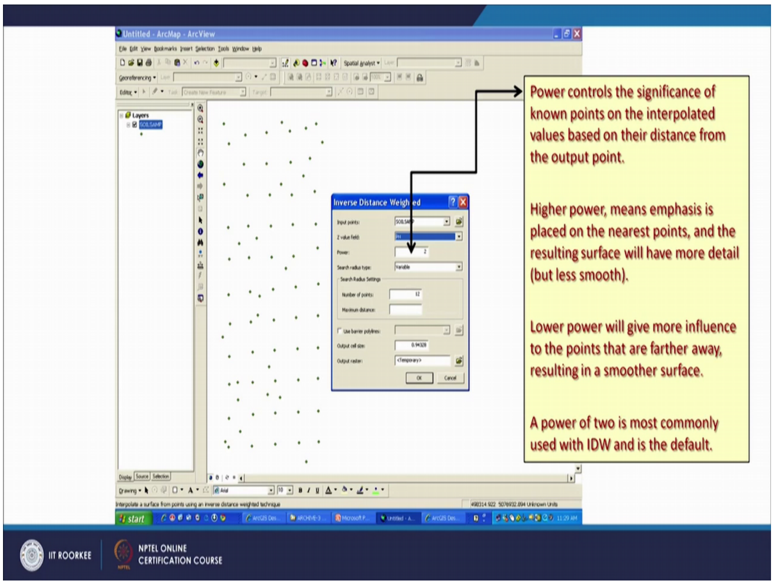

And for example here this is the example from a very popular gis software, which is arc gis arc map, and here the some soil sample data is being displayed which is randomly distributed, and a the method of interpolation has been choosing is IDW, and here what we are seeing that the pH value for we are considering as a z value for creating a surface, and a the number of points which will be searched around a unknown point are a in this particular example are 12.

Though you can also instead of a this search you can have a search based on distance as well; that means, a radius you will decide. So, you assign power; that means, a more influence or weight you can assign, and that is the power controls the significance or known points on the interpolated surface values, based on their distances from the input, higher point power means emphasis is placed on nearest points or resulting surface will have more detail.

So, you are assigning more weight to neighboring points rather than a far distance point, and a other one is the search radius.

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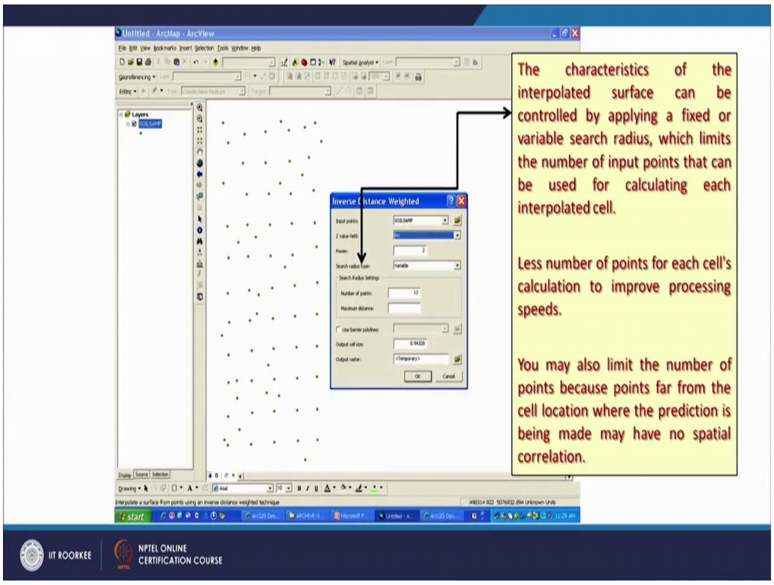

That the less number of points for each cell calculated to improve processing speed. So, if you put a more search point that it will take more time to search it will do more averaging to the point again, it depends on for what you are going to use this interpolated surface or a digital elevation model.

So, accordingly you will choose these, but in default in this particular software, the power is this given is 2, and the search radius or number of points which will be searched in neighborhood are only 12, you though you can change it or you can use the distance for such radius, and the third which is very important here all techniques will not support this one using the barriers, barriers can be supplied in form of polylines by various because if I am creating a surface, and I know I am going to use for groundwater related things then I want to put the drainage lines or river network, because they will influence my groundwater surface.

So, they I will consider as here the barriers, may be a geological structure may be a fault or other things I can supply while doing interpolations in a farm in a polyline form and file and that will use as a barrier, because faults make may influence the subsurface conditions or even on the surface conditions. So, these barriers are a important all techniques will not support barriers, only few techniques and will support especially IDW is supporting this barriers.

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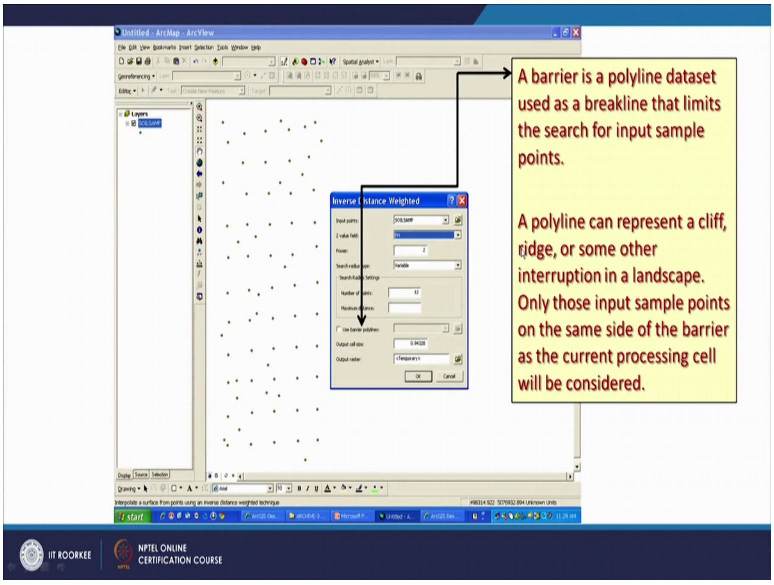

So, barriers is a polyline data set use as a brake line, that limits the search for input sample points.

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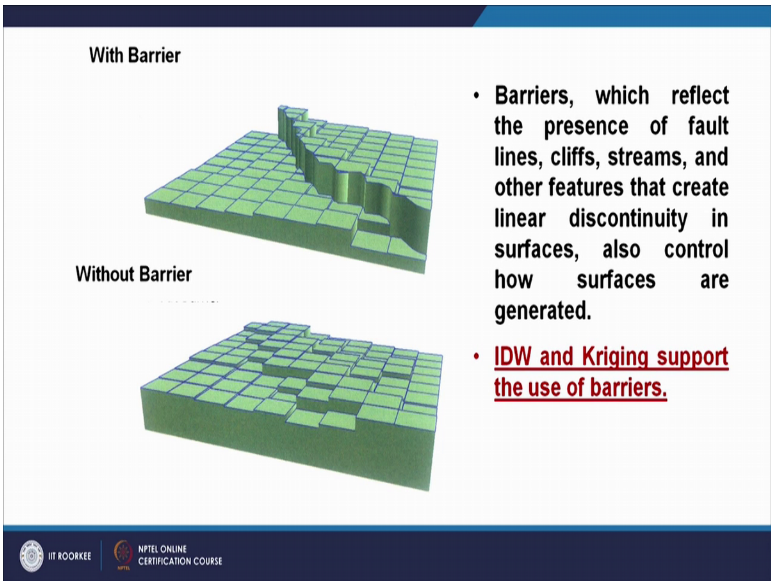

And if you see that a with barriers this is how a terrain in three d will look, and sometimes the scarf escarpments which we see on the land surface sudden change in the elevation, and these are nothing, but the barriers. So, these can be represented if we implied if we know the location of the barriers and supply any form of polyline file, if I in do the interpolations without barriers for the same terrain this is how it will look. So, this the with barriers looks more realistic this one looks more synthetic.

So, one has to be careful while choosing a particular interpolation techniques and barriers, that information has to be supplied before interpolation. So, barrier which reflects the presence of fault lines cliffs streams and other features that create linear discontinuity in the surfaces, also control how surfaces are generated, because if you supply that information then you can see in this particular example, how two completely different elevation models have been created using the same interpolation techniques, the difference is only about the supplying the information about barriers or without barriers; two techniques IDW and krigs.

So, IDW we have just come seen here, we will also see later the kriging supports the barriers other techniques like sp line, and a other interpolation techniques will not support barriers. So, again if a you your terrain is having such features then you are bound you should be using and these either of these two techniques to incorporate the information about barriers, this is the about the search points which I have been mentioning.

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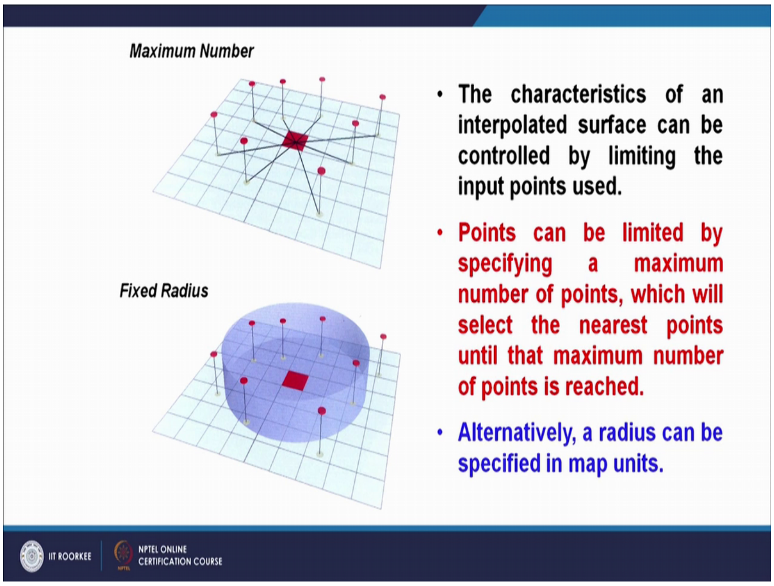

That a the search if you say that 12 points around a unknown location have to be searched.

So, only those points will be searched, but the same way I can constraint the system that search within the fixed radius. So, either you can give a radius and then in that case may be 2 points might be searched or a 5 point may be searched, it depends on the density of point observations. So, it depends on again your requirements, and you both options generally are supported by most of interpolation techniques, which have been implemented in standard gis software's.

The characteristics of an interpolated surface can be controlled by limiting input points, more the points you incorporate while doing a by doing the estimation, more smoother surfaces will create; however, it will take more time. So, points can be limited by specifying a maximum number of points, which will select the nearest points until the maximum number of point is reached, and the alternatively radius can also be specified in mapping units, and if you are working in a degree decimal then you have to define this distance in degree decimal, if you are working in meters then you have to define in meters.

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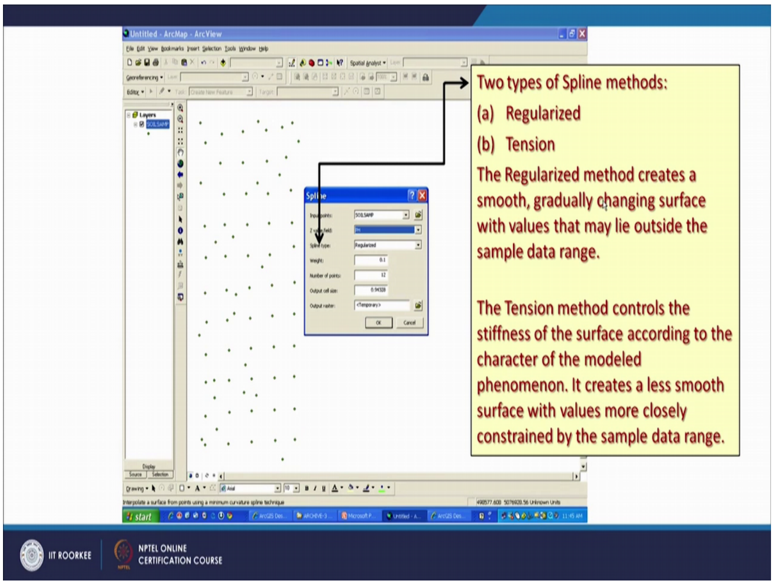

Now, if I go for another technique which is called sp line, then the options are different now here I can have regularized grids, again I can have a different weights number of points to be searched and so on so forth. now regularize intentions regularize methods creates a smooth gradually changing surface which values that may be outside the sample data. So, if I am having prior information of the terrain or the phenomena for which I am going to create a surface, then accordingly I will choose these options either regularize or tension, tension methods controls the stiffness of the surface.

According to the character of modeled phenomena; so knowledge about the phenomena is very much required, and third a non-inter non-linear interpolation technique which is very popular is creaking, because the advantage with creaking it also simultaneously creates a error surface. So, we know exactly how much error while interpolation is being done is has been created. So, that that is the biggest advantage, we will see in detail that creaking is a group of geo statistical techniques to interpolate the value of a random field maybe elevation shared value of a landscape as a function of geographic location, at an unobserved location from observations of it is value at nearby locations.

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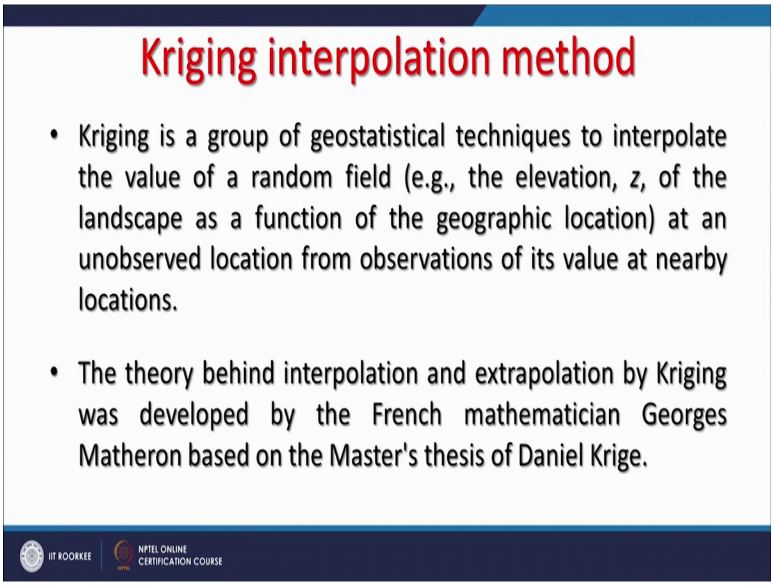

And that basically theory behind this interpolation and extrapolation by kriging is, that which was developed by a French mathematician George metron based on a master thesis of Daniel krige.

So, based on his a concept, and this a technique was developed and therefore, and the name as also been given kriging. So, kriging a stochastic there is something random also it is exact smooth or abrupt, global or local. So, it encompasses various and kinds of a surface representation if we see in a section or in a profile.

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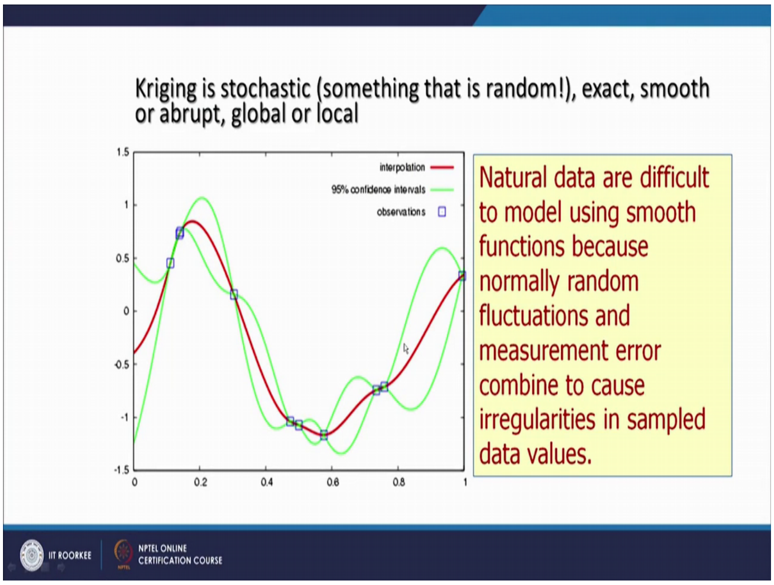

What do you find that through kriging we may be having a interpolated surface like this, but at ninety percent confidence interval, we may have a surface which is going above this line or a 5 percent here and there and another way also we can have a surface.

So, with the 95 percent confidential interval we can have these surfaces, and the input are these observations are there. So, depending on what we are what is the phenomena. So, natural datas are difficult to model, because using a smooth functions the normally random fluctuations and measurement error combined to cause irregularities in sample data values as we can see even at 5 percent inter 95 percent confidence interval, 2 completely different surfaces can be created.

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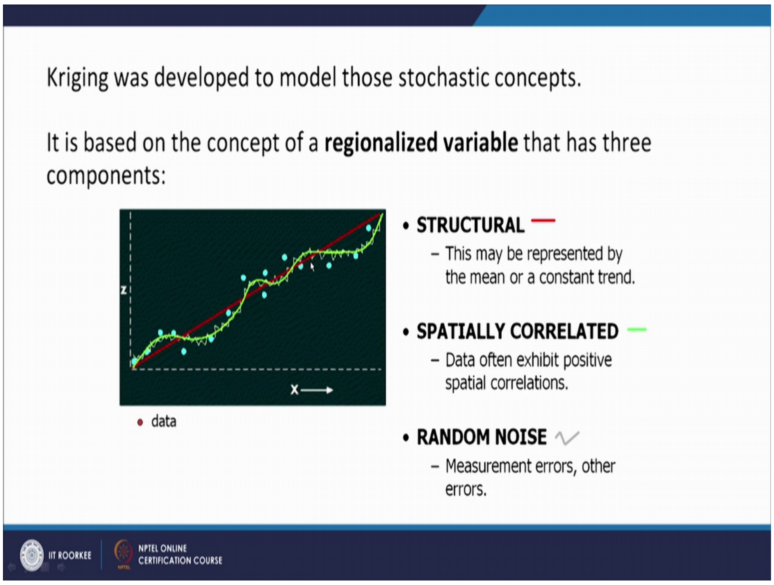

So, here now kriging was developed to model those stochastic concept, and which is based on the concept of regionalized variable that has three components all three together are here, but we can see one by one, that one is the red one is the structural component this may be represented the mean of a constant trend, or a spatially correlated component that is the data often exhibits possible positive or a spatially correlations, or random noise which is also soon is through a zig zag file.

So, point observation the data are is here the structural trend is there, then you are having this spatially correlated data is here, and then random noise and this noise is the measurement of errors and that is the advantage of having kriging, kriging can give you a red surface, and that let us you know that where errors are there while interpolation has been done, no other methods can estimate errors while doing interpolations.

So, what are the components of a regionalized variable, as I have told you that the same display can be splitted that a structural component.

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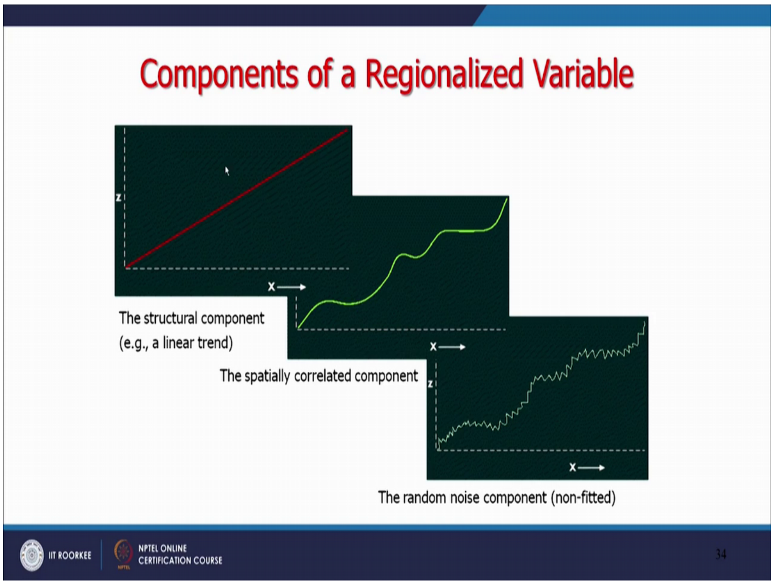

Then spatially correlated component and third is the random noise, which is an unfitted component here. So, all these components are there in a regionalize variable.

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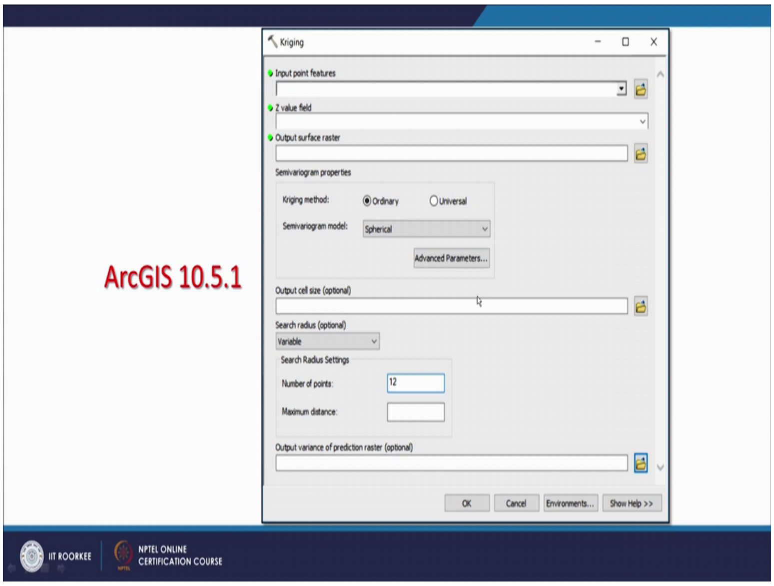

If I take the example of latest version of our gis arcmap, 10 5, 10.5.1, this is how a gui for kriging when you will choose from toolbox, a kriging method these are the things which you can use in a aggregate you have to provide a input point feature file, or point file, and choose a through at ill among the attributes which attribute you want to consider as a z value.

Then where you will store the output surface, then two methods ordinary and universal these are there, and then semi wave gram models are there is spherical and many other options will be available, what should be the size of cell; that means, that you are now fixing here spatial resolution of the digital elevation model, which is going to be created using kriging, will be here then number of points during the search again by default you are getting 12 values, you can reduce or you can increase more the search points you will ask, more the time it would take more the smooth surface it is going to create whereas, if you are having large distance the same thing it will take more time more smooth surfaces can be created and finally, you can have as you can store the your result sets at well.

So, this is how a typical kriging interface input are required while creating this one. One of the very useful outputs from kriging analysis is the uncertainty surface that can be.

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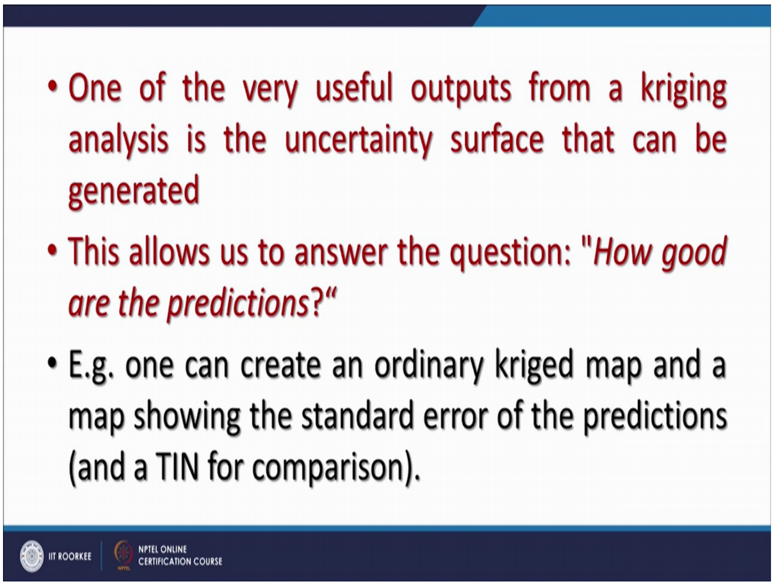

Generated, and this allows us to answer question major question how good are the predictions, because other techniques do not support this one the error surface or in very crudes terms you can say error surface for example, one can create an ordinary kriged map, and a map showing a the standard error of prediction, and a we can compare say for example, with a TIN.

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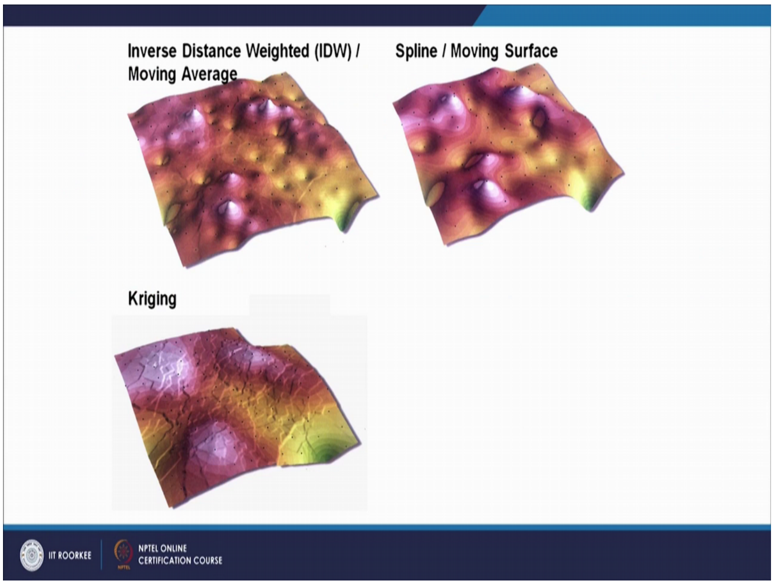

So, here using different techniques an example is shown, that using the same data point data sets same data point data has been used, while creating a surface using IDW method, then here sp line method and the kriging method, you can see that how completely different surfaces have been created using three different completely different interpolation techniques, though IDW and sp line are producing a little closer surfaces, but krig kriging surface is altogether different.

Now, there will be a question that if I am having a set of points, I want a to do a created digital elevation model, which interpolation techniques should I choose, and that is a, it is a that is very, very important because we do not know because everything is being estimated or predicted, whether predicted surface is close to the reality or real surface how we will check. So, there are some methods which we will be discussing later, that these can be employed in a very simple way to check which interpolation technique is more suitable for my input dataset, and the there a once you have decided then for entire dataset you can do that one, and if we are we continue on this if we.

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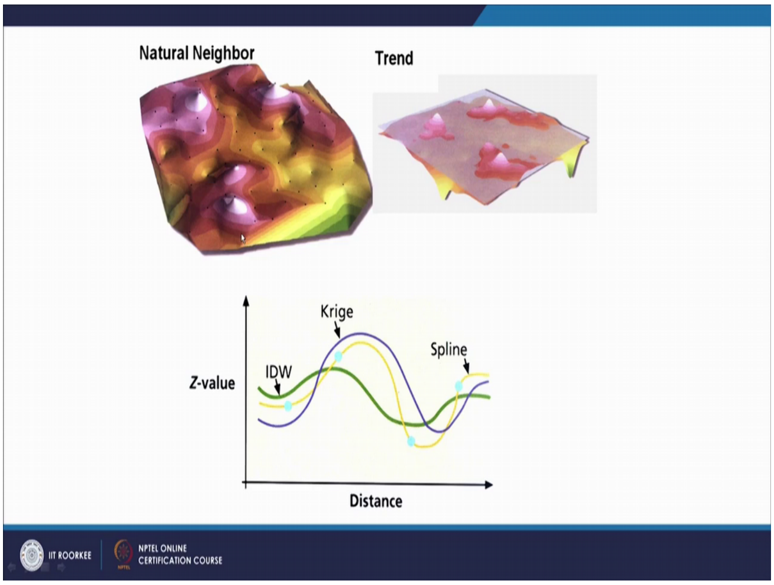

Instead of seeing surfaces like here if we see a profile of all these threes surfaces, and also locations of observation points point data is also shown, what do we find here? That IDW is the surface is going like this in this schematic and whereas, your a this sp line surface that is in yellow color is a absolutely fitting with all data points, and where is your krig surface is going above and lower of these.

So, depending on the data and the variables which you have chosen different or respective interpolation techniques, your surfaces will be created. Now what are the problems of interpolation, the problem the first one as we have already discussed in little briefly about the accuracy, how accurate this surface which I have generated through a set of points, using a particular elevation mod a interpolation technique.

So, that is that is a main question this will be all the time when you produce a interpolated surface this question can be asked. So, accuracy assessment has to be done there.

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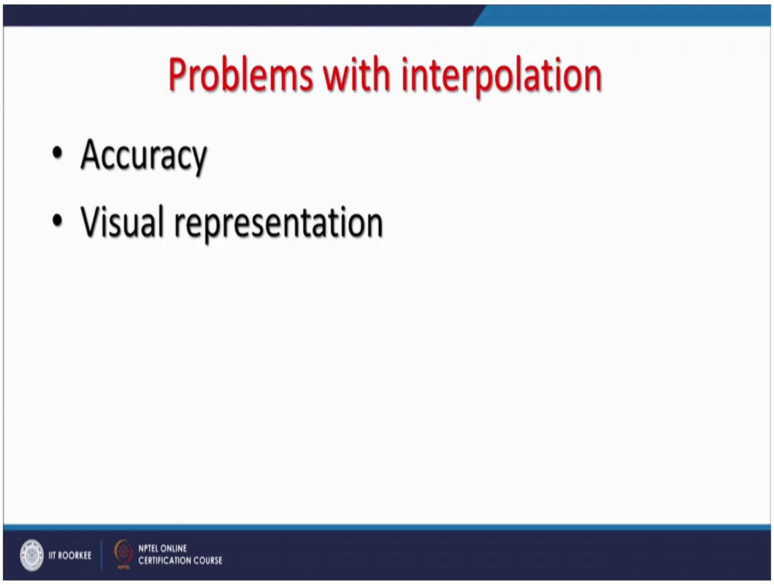

Are ways either you imply the differential GPS data to check how interpolation is done, or compare your data with maybe a same resolution digital elevation model or maybe a little higher or lower spatial resolution model, and through which you can check or already using the input data which you have used, for which the data observe a observed data where there you can compare with that and can find out that how the best interpolation has been done.

Visually in representation can also be used to see this a problem, and this is a quick assessment of a part of that one, a at some time back I told the edge effects because at the edge is you do not have beyond edges you do not have the observation and therefore, own edges or margin of your data set or boundary of your data set, you are creating interpolation extrapolations, and that extrapolation will might bring lot of errors.

So, the best solution to this problem is, that a if you are having your area is a not as big as your observation points, then do the interpolation for entire set of points and then extract the area of your interest, and by which you can avoid the extrapolation. So, this is one quick way of a you know nullifying this a edge effects, a we will be seeing also through software the demonstration.

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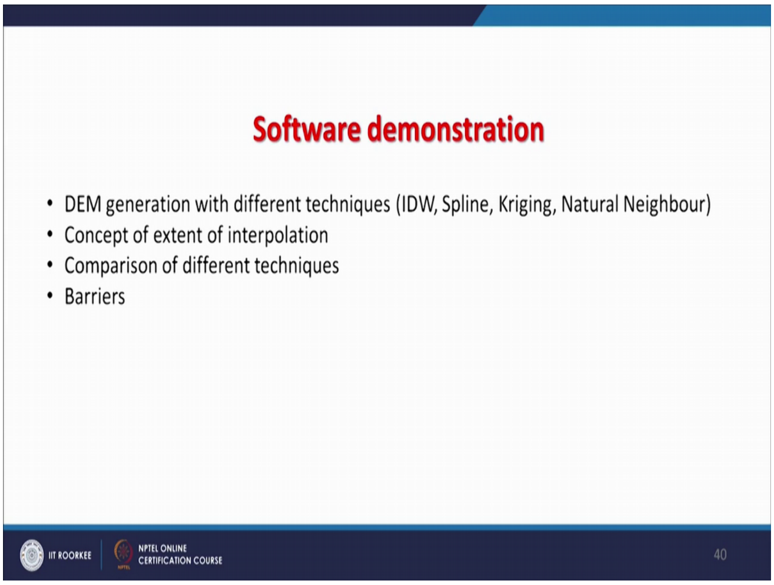

By a creating a dm using different interpolation techniques, also the we will be seeing the concept of extent of interpolations; that means, the edge issue and we will try to compare different techniques which we have already discussed, also when we go for interpolations we will also see and the issue of barriers.

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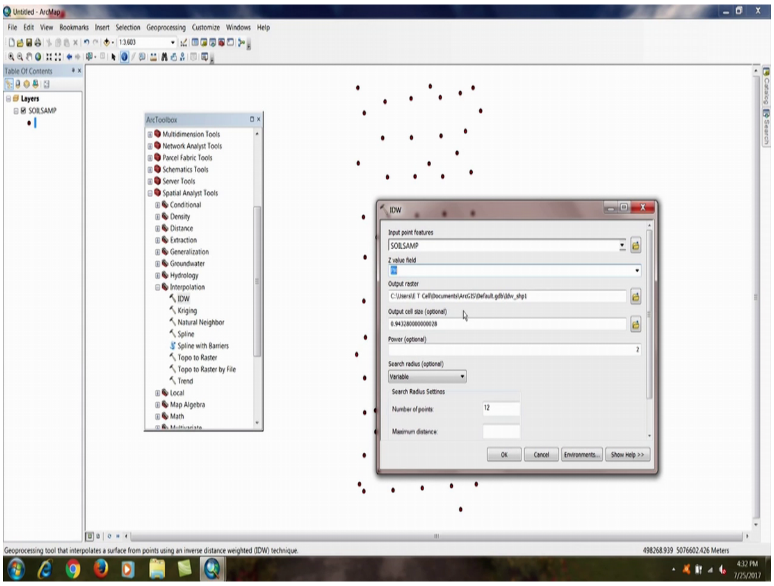

So, in this demonstration of the this is of about this discussion which we had about a how to create a surface, or digital elevation model using point data. So, again I am using this arcmap and ArcGIS software, here we have to use a some tools which are available within this software. So, when we install this one a spatial analyst extension is also installed. So, I will be going to that and then interpolation options, and they say for example, if I go for IDW.

So, I am going for IDW, we have all I we are already having a point data. So, now, I will take a the point data here the file, and one of the fields which I will use numeric field, which I will use for interpolation. So, here I am because this is soil data. So, I am going to use the ph because, as mentioned earlier that the in digital elevation model or terrain model, ors d dsm it is not necessary that all the time we should have the cell value as elevation value, we can have any value even a ph value or a electric conductivity value or a pollutant world.

So, concentration of pollution or any other values in there that is why I deliberately I am taking example, were instead of valuation we are taking a ph value, and a rest of the things are here I can here I can also control the resolution of a dm which it is going to be generated through this interpolation technique.

So, for time being I am taking a only whatever is it default, also I am using the default power because, if I increase the power it will take more time and it will create more smoothened surface as discussed earlier, now here in the default the search points are twelve because it is not a very dense data it is not a big point data set. So, this this one is a sufficient here the search radius I can fixed or I can have a variable.

So, I am going to have a variable, now in this IDW also allow us to use the barriers, for time being because it is a soil data. So, no requirements of barrier, but if it would have been a groundwater surface data, water table then variance will play very important role, or it would have been a surface data and in case of runoff studies if you are having dikes or other a features faults, then a input barrier input is very much required.

So, if I go there and a accept all these options, go for interpolation it will be doing now interpolation go what happened.

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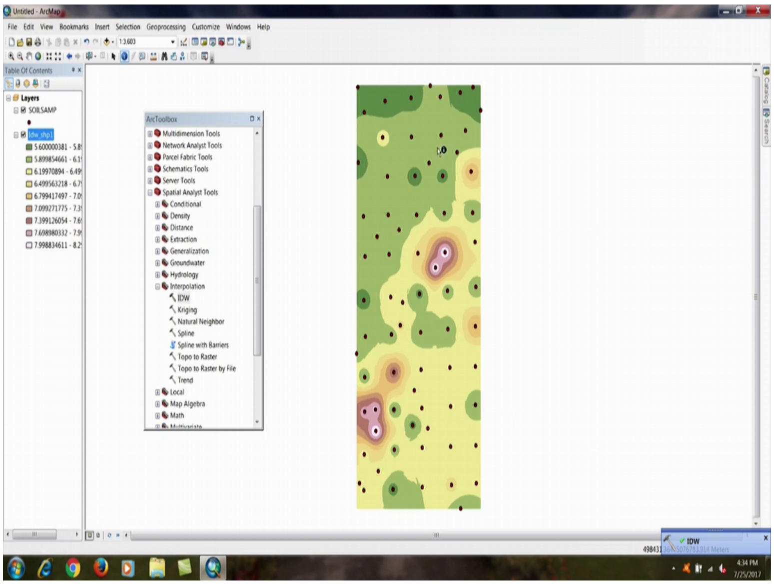

So, now it has a as you can see, and it has created now interpolation only up to the extend here is only up to the extent of our in-point data set, because this is what we have chosen if we go for a extension which is say whatever in the view, then it will a extrapolate the values there which are going to be definitely very wrong.

Now, a how good interpolation is, and by this IDW and it especially with this data set, this can also be checked if a we go for this thing and a they say I just want to search that a what happened to my these input points, against the new values which have been created through that generation of a digital elevation model. So, when I go here, I can search a all two layers together.

So, I am going for all layer’s selection and now when I click here, now it tells me that in the original value was 20, and a this a the value which it has a sorry the original value was 8.2, and a the interpolated value is also 8.2 as you can see, in this dm the name of the dm IDW under course shape one.

So, this is the input value which is 8.2, and the interpolated value is also 8.2, let us see some other example here, for example, here the ph value is 6.5 also it is also 6.500. So, quite close to that one. So, in a if I check another value it is again 6.4 6.40042. So, it is very close and therefore, for such type of data, what we are finding that IDW interpolation is a quite good.

Now, let us a let us try some other interpolation. So, what we will do, we will try switch off this one take this one again and say I go for sp line. So, again here same data set same field I am going to has. So, that we can compare, and a the cell size I am also keeping same, here instead of a tension I am going to have a reguli, but this is optional and a also we can assign the weight here, beta is already assigned point one, it is sufficient and the such radius and this much, and they further if I want that a if I want to go you know the search radius or you want to change again I can change, but I am not going to do it.

So, let us go for sp line, by the same field z value for z value we are using the same field, and then later on we can compare here it has created for sp line as well. So, now we can see the interpolation done by two techniques, and our original points. So, let us go back and see that a if I click here, what it is telling and that a this is my original input the point data value was 8.2, through sp line I am getting again 8.2 and also from IDW I am getting.

So, in that way for this particular data set, let us check another value this value this value is also know, here this value is input value is 8.2 interpolated value in sp line it is 8.2, but a in a IDW quite close 8.199, and let us check some other values also, and some other input values we will see here like for example, one value is here. So, if I click on this one I get 6.4 that is a my input value IDW, through IDW interpolation again 6.400 or 2 whereas, in sp line it is going little away and it is 6.38. So, if we round off it would be 6.39. So, quite close.

So, for a small data set and if values are not vary too much means, the input values or the values in that particular field which we are considering for z value, and then it is likelihood that we will get a interpolated values as well and close to the original values. So, by this I have also we can see that how it is looking something that way we can check very well and overall also, this is the overall dm using and using IDW this is IDW and this is sp line and the color scheme is also same, but the range since a in this classification the ranges are different therefore, when I click one after another there are two different patterns are coming, but probably the data wise it is almost same, in this sp line as you have seen that the sp line does not support the barriers.

So, barriers are supported by limited interpolation techniques, example like IDW, but barriers are not supported by all interpolation techniques as given here, as you can see that in this particular software IDW is supported kriging is supported and natural neighbors are and a this one is a common for other and then sp line, and some other trained surfaces are also there. So, in this particular lecture we have a bury in the beginning we have discussed the various types of a interpolation techniques, but in this one basically, we have focused how this using a topographic maps or point data and implying a spatial interpolation techniques and different techniques a by which we can create digital elevation model.

So, thank you very much.