Geographic Information Systems

Prof. A. K. Saraf
Department of Earth Science
Indian Institute of Technology – Roorkee

Lecture – 07

TIN Data Model and Comparisons with Raster

Hello everyone! and welcome to new discussion of this course. Today, we are going to discuss Triangulated Irregular Network that is TIN data models and we will try to compare with the raster data model. Because both are continuous in nature and therefore true comparison can be among these two data models and in between also, I would be mentioning a little bit comparison about vector data also.

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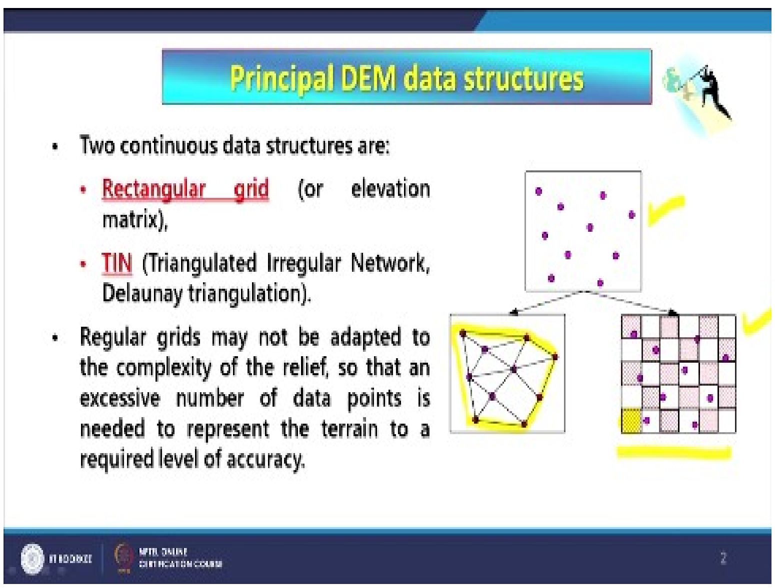

So, let us first try to understand what basically TIN is? As mentioned that both raster and TIN, are the continuous data structures. Raster; we have discussed sufficiently that is a 2 dimensional matrix of course, it is continuous. TIN instead of having unit in case of raster- a square, here we use unit as a triangle but the shape and sizes of these triangle are adaptable to relief changes and that is why the word irregular network of triangles is used here.

So, irregular network which is based on a Delaunay triangulation method which we will also touched upon it. And as you can see here that the input data in both the cases can be like point data and if I talk about this surface or raster (this one) then through interpolation techniques, we can develop such surfaces using the point data which is given here. And if we use the same data set and develop a TIN model, this is what going to happen.

The important point here is which you have to see that what happens on the margins of when TIN is developed because in case of using point data and creating a raster through interpolation techniques, we can decide what should be the extent of our raster and also we can instruct or we can decide what is going to be the resolution or the cell size equivalent to ground.

But here in case of TIN, we do not have any control over the margins like it will go up to where the data points input points are there. And also we do not have any control over the resolution because resolution here is basically will be controlled by triangles and triangles are adaptable to relief changes and therefore there are large triangles, small triangles and so on. As you know that regular grids are not adapted to complexity of relief.

And whether it is a flat area or a hilly terrain; the same size cells or pixels are used to represent that surface. But in case of TIN as I have been mentioning, it is adaptable to relief changes and therefore many times especially in highly rugged terrain, one finds that TIN to some extent better represents the terrain ruggedness or relief compared to raster. We will be further seeing on this aspect also. So, triangulated irregular basically is also a surface representation.

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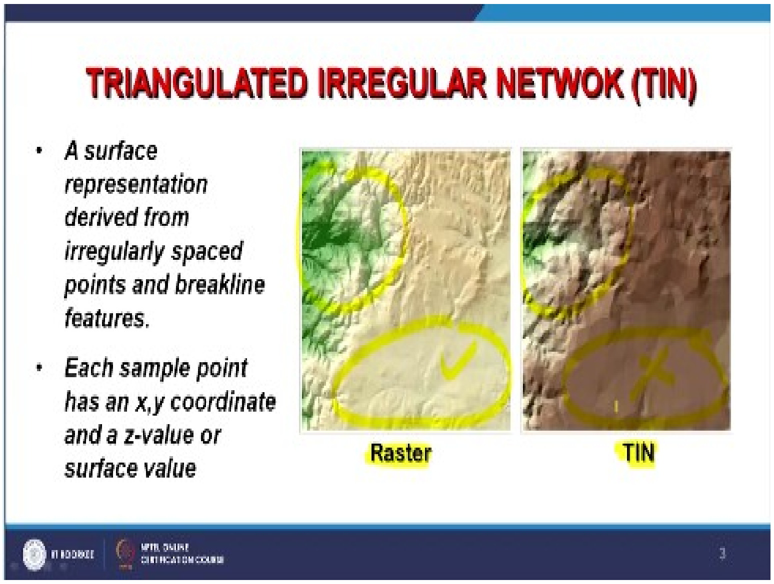

And it is derived from irregularly spaced points and break lines. Point is always input here if somebody is having poly-line data, no problem. Poly-line can be converted to point because after all poly-lines are also having series of X and Y's. So, we can convert or some smart software is capable now. If you provide input in poly-line, they will convert first into the points or use these nodes and internodes and create it in. So, that is not a big issue.

Break lines; we will discuss quite very soon. Now the raster data, the same terrain has been represented in 2 formats or models. One is the raster as you can see here but when we compare raster with TIN; see little different representation which is what we are seeing here, especially when we are having high relief area like in this part and then we find that TIN maybe better representing in a better manner.

However for flat areas, it seems that the raster is representing better and whereas, TIN does not have that kind of flexibility. So basically if you open a book or literature or any website and you would like to know that which model is the best for your work then you would never find that answer. It basically depends on the input data. How? What is the density of the data? Means density of observations and also for what purpose, you are going to use different models.

So, for certain purposes; point's data can be converted into line data or poly-line data. Contour data; many people are very convenient, very comfortable with the contour data. So, they would prefer that one but some people are very-very convenient and very comfortable with raster data because raster data can be used along with satellite data in various products of remote sensing and many other data sets also.

But some people may prefer TIN because the ruggedness in the terrain for the project area is very high and it represents in a much better manner. One more important thing is raster is not as that compressed as TIN. So, TIN in many ways is very efficient model, not only to represent the relief roughness in a much better manner but also it does not occupy much space on the hard disk. So, these are the very important points related with the TIN and when we compare with raster.

Of course, here also when we provide the data for generation of TIN, three things are very much required or essential. One is x coordinate, y coordinate is a pair maybe many-2 points. Like here, when I was showing, these are the points and one more value you have to provide and that can be elevation value that is the Z value. So, Z value is also provided here to create the surface whether TIN or raster.

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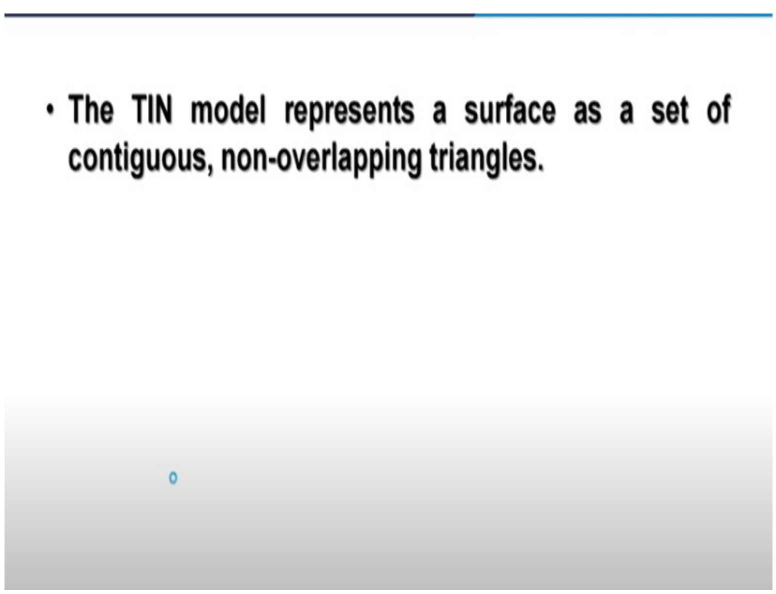

Now this is another important thing is that the TIN model basically represents a surface or terrain as a set of contiguous non-overlapping triangles. That means there is basically no gap; continuously one triangle ends, another starts. Same as in case of raster; one cell or pixel ends, other starts and there is no gap between 2 pixels; 2 cells. Same here, there is no gap. So it is a contiguous and non-overlapping. Also, that there is no overlapping between triangles same in case of raster.

And each triangle is represented by a plane or facet, we all also called. So within that facet, you may have little variations especially about the information; about slope and of course, aspect would be fixed for that. That we will see also quite soon. Now triangles are made from a set of points that is called mass points.

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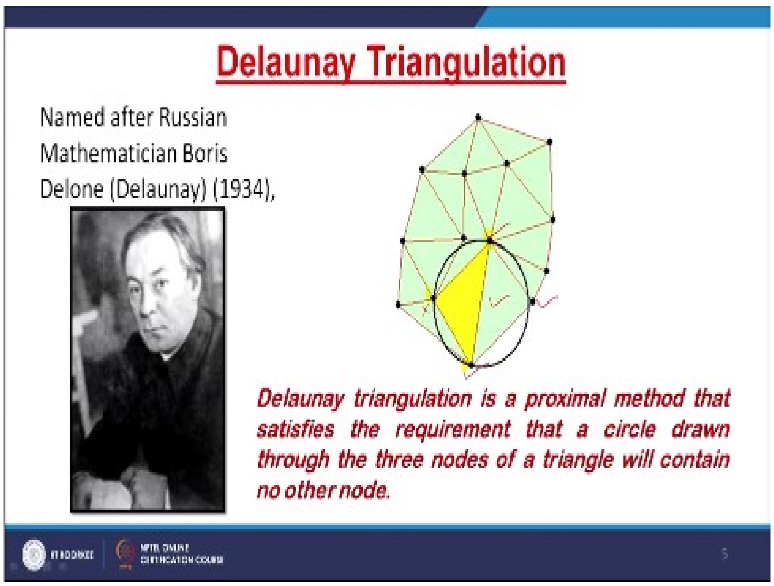

Because the input is always data and now a little bit dedication to the person who gave this idea. That is Boris Delaunay and in 1934, he gave this theorem basically this triangulation, it is still known as the Delaunay triangulation, basically say proximal method that satisfies the requirement. What is that requirement? That is if a circle is drawn through the 3 nodes of a triangle, that will contain no other node.

So like here, the example is shown that around this yellow coloured triangle when a circle is drawn, no other nodes are present except this one, this one and this one. So, this is what the Delaunay concept says and you can test this thing on any other location within this figure or any real output often that it should satisfy this. That there cannot be any other node except these 3 and that is why a triangle is formed.

So if I want to cover say this triangle then this has to be shifted this circle. So which will touch this node, this node and this node and will not touch this node and likewise for each triangle, this is satisfied. So that is why it is called Delaunay concept.

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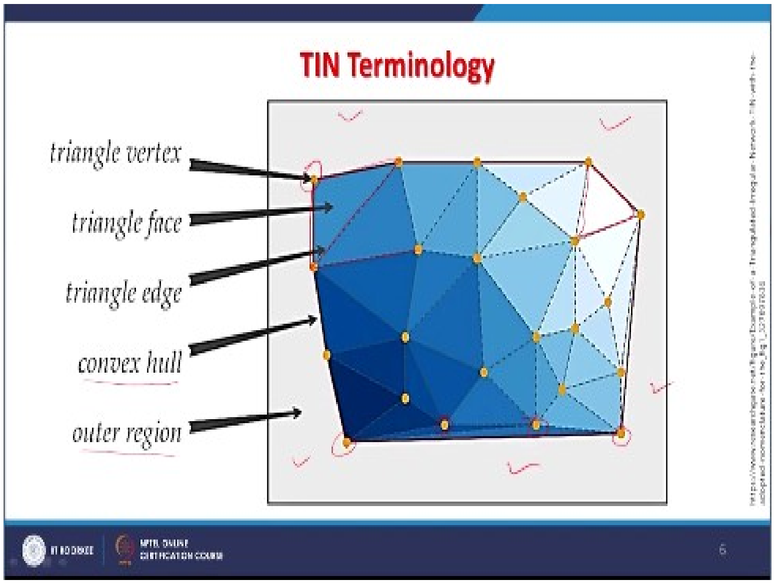

Now different terminologies or terms which are used associated with TIN. One by one, I will touch upon that. When you are having this triangle vertex or the input points so, we call it as vertex. Overall everything is called mass points whatever the input points are there and this is what is the triangle and that the face or facet. So, that is a plane. Here this is the plane between 3 triangles.

Now these are the edges of a triangle and then you may have a convex hull or concave also and then outer region. That outer region is very important because the boundary issue with the TIN is you know, sometimes we may find it is a limitation. Also you would see that if like in this example though we say you know not a real example, is schematic one. Nonetheless in real also, many times we see like this.

So if all points are aligned like this; this point, this point, this point and this point and we have to satisfy that the Delaunay concept or theorem then these triangles are though made but very elongated one and though there are triangles. There cannot be any other shape of the unit. The unit here is always has to be a triangle.

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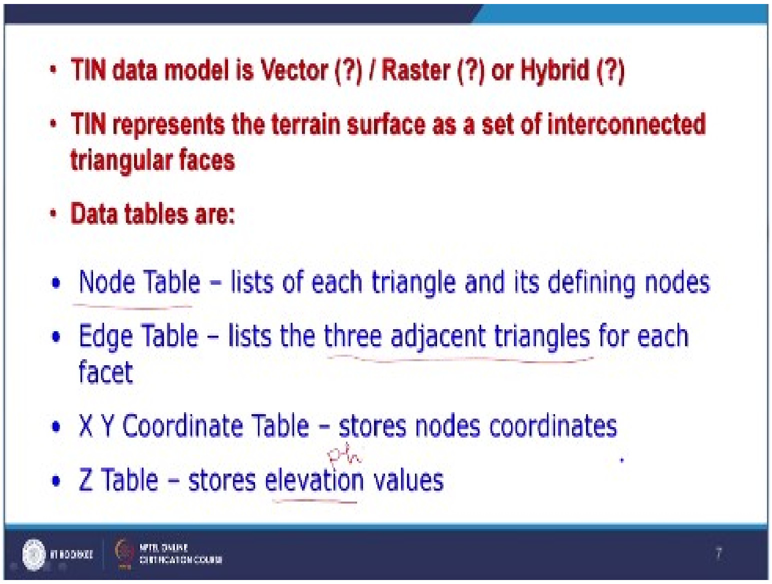

Now sometimes in the early literature you know, authors of different books have kept TIN as a vector entity, as a vector model or later on maybe some people have kept more close to the raster or hybrid or a separate model. I personally feel that TIN is neither vector model nor raster model and it is not really a truly hybrid model also because the concept here is completely different then vector and raster.

But the best part is that almost all, good GIS software's have implemented successfully. Though, the concept as you know was developed in 1934 but the real development of GIS has taken place often early 60s. So, TIN represents the terrain surface as a set of interconnected triangular faces as you have seen in the just previous slide and all everything is managed like in vector data or when we were discussing about the polygons.

When they are having the topology built with them then everything is organised in form of tables because this is how the computer stores information and this is how the GIS understand. So, there will be many tables for TIN model. So, first are the node table and node table will have a list of each triangle and its defining nodes. We will see with the examples also. Then edge table because they each triangle will have an edge and that information has to be also stored in the system.

So, all 3 edges and triangles for each facet and then you are having of course, the mass points or X, Y coordinate table which stores the node coordinates and finally the fourth one is the z table which will store. Here in default, we are writing elevation value but this value can be pH value or can be any other parameter so that one does not have to bother. In general, we always call as an elevation but elevation does not mean it has to be always height value.

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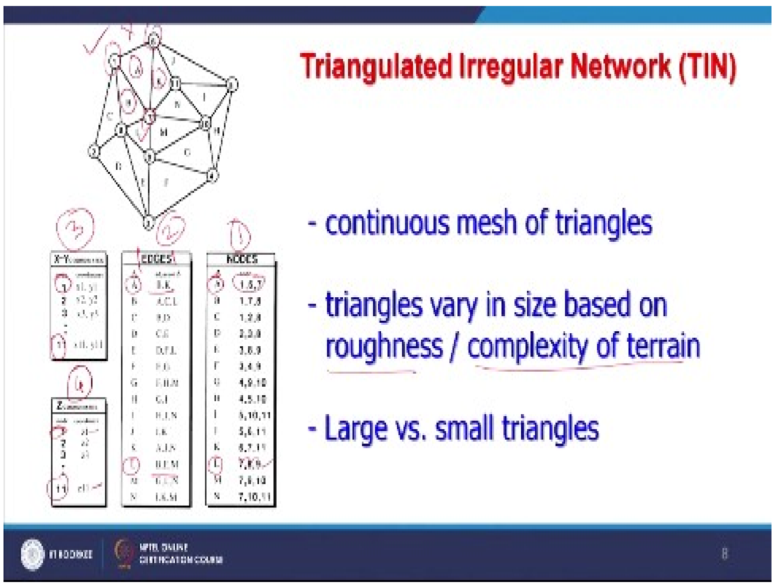

Now, here you know a triangle with 4 table examples. So the first one, which we discussed was node table. So, node table as you can see, there is a list of triangles and all nodes which are constructing that triangle. So, if I take this example of triangle A; triangle A is here which is made from 3 nodes- 1, 6 and 7 and this is what you see 1, 6 and 7. And let me take one more example if I say this triangle L; then triangle L is here which is here, which is made from node at 7, 8 and 9 so, 7, 8 and 9.

So, the node table will store information about the nodes of each triangle. Now, the next table is edge table or edge's table which is here and the same way if I take the same triangle A then there are 2 edges because this is border area; the margin area. So here, we do not have any information but B edge and K triangle edges are being shared with this triangle A that is why they are there.

But if I take the triangle L example then it is having 3 edges because it is inside our TIN model. So B, E, M. So for L; what are the B triangles, E triangle and M triangle? All 3 are making and the maximum you can have just 3, you cannot have 4. For a minimum, you may have 2. So both examples I have taken. Now the third table which is the X, Y coordinates table or coordinates table will have series of X and Y against each node.

So, if I take node 1 which is here; node 1 is here, it is having X1, Y1; one set. Similarly if I take the node 11, it is having X11, Y11 and so on. Now, the last table will store basically attribute value of a point file. That attribute value maybe your elevation value, maybe pH value, maybe soil moisture value, maybe water depth value, groundwater depth value, any value can be used as a z value and here for say, node1, 1; node 11, Z11 and this is of course variable. So, depending on the real conditions.

So, this is how a TIN is stored in the system, this is how it is organised so that efficiently we can use it. Now as we have already discussed, it is a continuous mesh of triangles. The only issue will come which we will also discuss in much detail is about the margin or boundary area. Triangles vary in sizes that is why it is called irregular network of based on the roughness, terrain roughness or complexity of terrain.

If terrain is very complex means there are high undulations, very high roughness then smaller triangles will be formed and if terrain is flat, let me give you an example. The example like if I am working in a part of Himalaya then I will encounter a very rough terrain in terms of relief roughness or terrain is complex and therefore in order to represent a part of Himalaya through TIN, smaller triangles will be formed.

But of course, here the important point is what is the density of observations that will come through mass points. So, mass point's density should also be very high then only small triangles will be formed. Otherwise accurate representation will not be possible through TIN and similarly if I am developing TIN for Indo-Gangetic plain which is almost flat terrain, the larger triangles will be formed.

However, mass points may be having the same density as in case of Himalaya but still larger triangle will be formed because the relief roughness is not there. Terrain is not complex from topographic point of view. So, this is adoptable. So, this is done on depending on your input mass points and terrain roughness. So, this one has to remember and therefore these small large triangles, keep going on.

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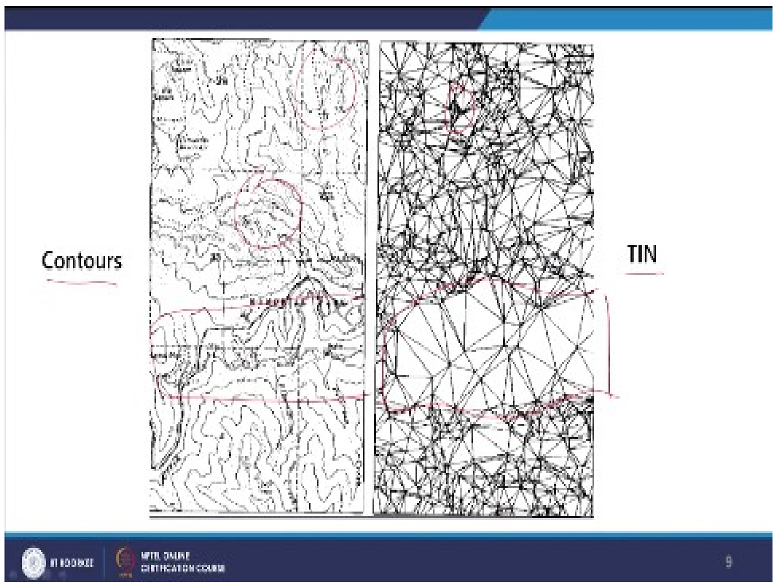

Now let's take a more realistic example, here you are seeing on the left side, the contours representation i.e. representation of terrain through contours. And on the right side, the TIN was constructed using of course; contour values or contour data. So, as I earlier mentioned say, poly-line data is made from points. So, those points can become our mass input points and we can use to create TIN.

Now when TIN is created, as you can see in this part, especially in this part; larger triangles are formed because if you see carefully. Here also in the part of contours; contours are having quite large distance as compared to other parts. Like other parts are having you know, dense contours. So, more the distance between contours having the same interval system as in other parts and then larger or smaller triangles will be formed.

So, here you can see very dense triangles have been formed means smaller-smaller triangles have been formed because the biggest advantage of the TIN is, it is adaptable to relief roughness and therefore there are hardly any redundancy in the TIN. Whereas a raster, typical raster grid or a digital elevation model is not adapted to relief roughness and many times you would find, there is a lot of redundancy and therefore you can achieve good compression with raster.

But TIN, hardly you can achieve any compression because TIN by nature itself is a very you know compressed model.

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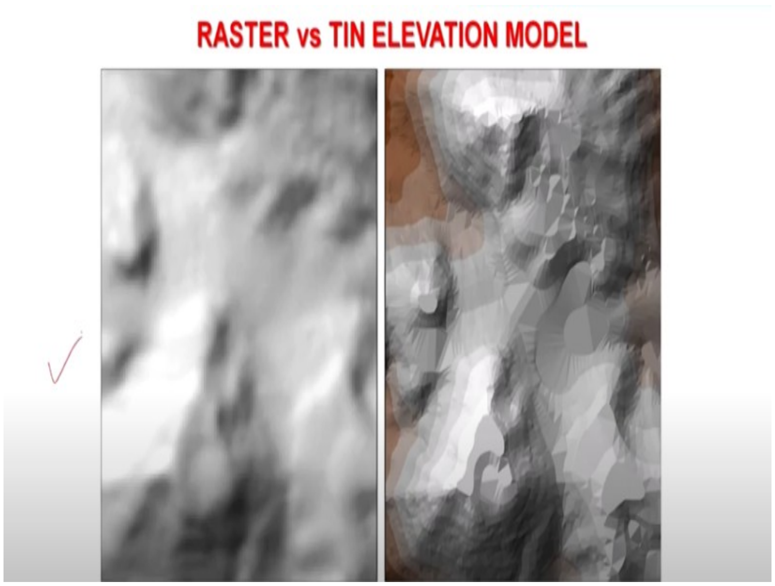

Again the real example, on the left side you are seeing the digital elevation model and for the same terrain, you are also seeing the TIN. As you can see the TIN looks more realistic as compared to your raster. So, this is another very important point. I will tell you why also it looks more realistic than raster? We will discuss that part.

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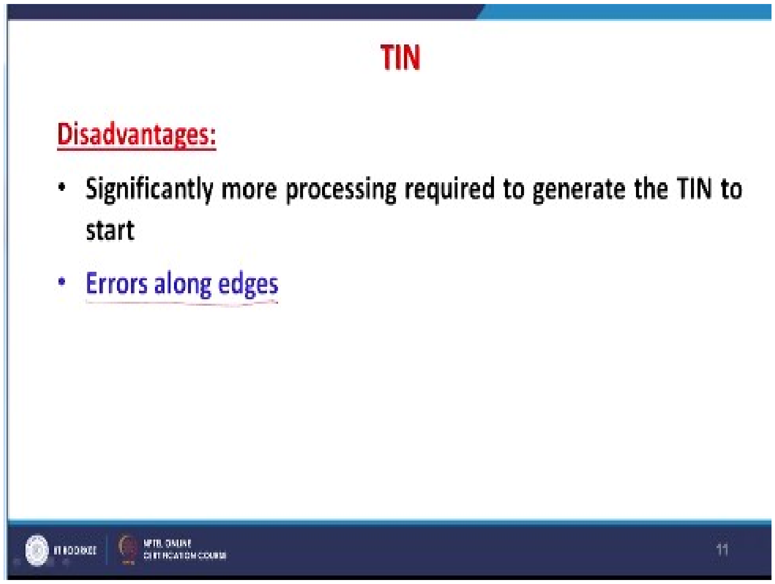

Before that, we will compare this TIN versus raster and we will see what are the advantages and disadvantages associated with TIN. So, the first disadvantage is that significantly more processing required to generating the TIN to start. If you are having you know, very large number of mass points or input points then it will take more time to generate TIN because for every 3 points, it has to satisfy the Boris Delaunay theorem.

And then this issue will also be there; errors along edges. Edges mean the boundary of overall TIN or input points that issue will be there.

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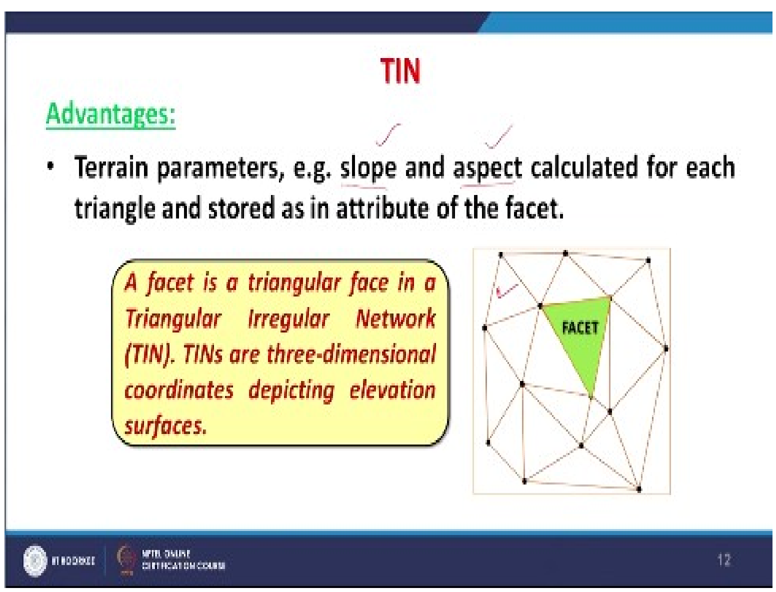

And now advantages; we have been discussing that not only it is adaptable to relief roughness but when you create TIN; it also creates slope and aspect. And that is why TIN looks more realistic when you display for the same terrain as you are having raster. In the previous example, I have shown to you. On the left side, I had the raster. On the right side, I had the TIN and TIN was looking more realistic because the slope and aspects are also calculated simultaneously when TIN is created.

So, you do not have to calculate for them. But in case of raster, you have to perform these steps. Though, nowadays software does not take much time to calculate these derivatives of a surface or digital elevation model. But nonetheless, one has to create. So here, in this facet example, here is a triangular or in a TIN, these are the 3 dimensional coordinates depicting elevation surfaces or facet or plane also, we can call it.

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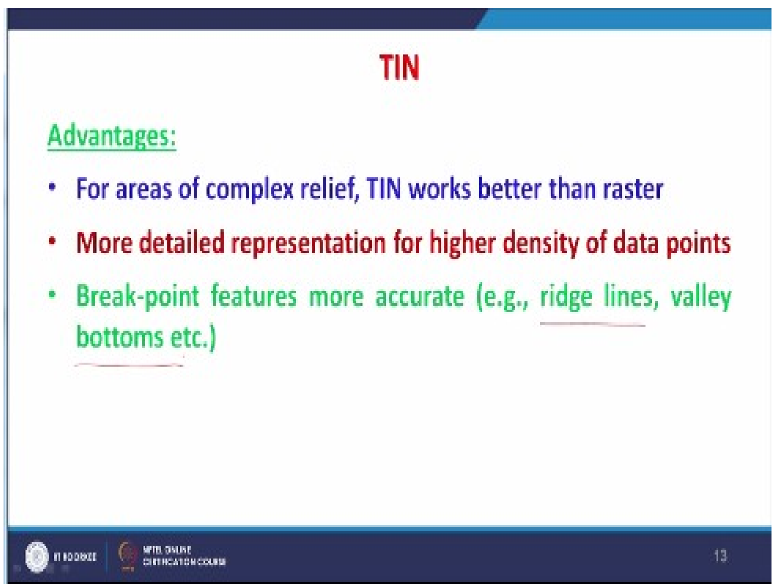

Now here, the facet example is given and now we will go through the advantages. Some we have already touched that the areas of complex relief; TIN works better than raster. I have shown you the examples also. So, it is adaptable to relief roughness. A more detailed representation for higher density of data points in case of raster because it will take inputs based on the spatial resolution which you have fixed for creating a raster.

But here, it will depend on the density of input points. So, that is one of the very good advantages of TIN. Now, breakpoint features more accurate; breakpoint features when you create a raster, you have to provide these breakpoints or break line features like ridge lines, valleys or bottoms etc. So, these may not be represented very nicely in case of raster but in case of TIN these are very nicely represented.

On breakpoints, we will discuss further when we will be discussing the interpolation techniques using point data or creating raster. At that time, we will further discuss and build see how software handles these break lines. Instead of calling breakpoint, the software calls as break lines. Break line is more appropriate term.

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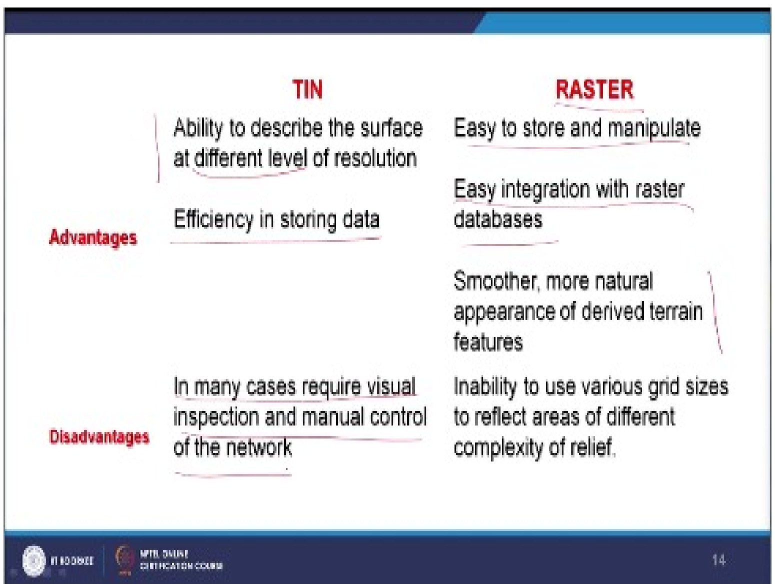

Anyway now, in summary that advantages and disadvantages associated with TIN and raster that it is ability to describe the surface at different level of resolution because each triangle maybe having different size and shape. So, that is why it is having a different resolution. But in case of raster, the resolution is fixed though raster is easy to store, easy integration with raster data bases like satellite data or other data. It is a smoother, more natural appearance of derived features whereas TIN is very efficient because hardly there is any redundancy. If we look at the TIN disadvantage that many cases require visual inspection and manual control of the network but here, it is not. The disadvantage associated with raster is that inability to use various grid sizes, within one data set. Suppose I am having point data, I am creating TIN as well as raster using the same point data. While creating raster, I have to provide what is going to be with my resolution and that is fixed for an entire file but in case of TIN, that information I do not have to provide. So when we will see the demonstration, these points will come again at that moment.

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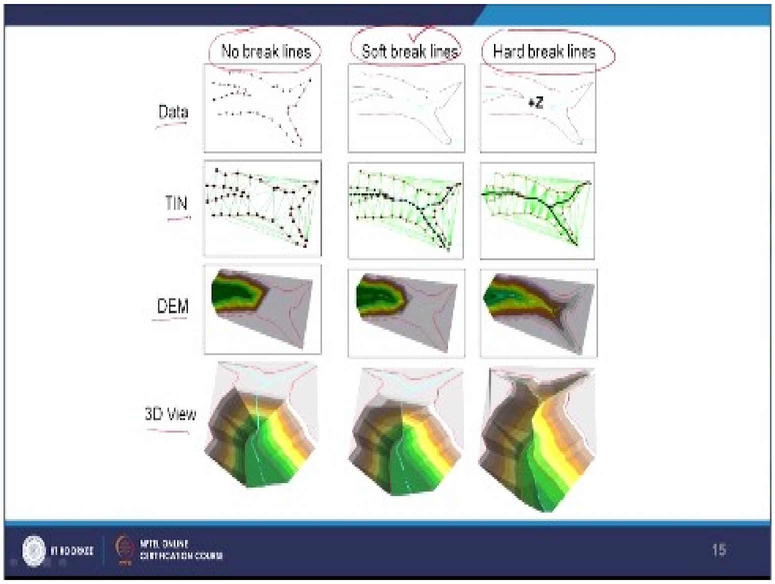

Now break lines that through software are also, I will be trying to show but if I generate a surface TIN or DEM: digital elevation model, here we are having no break lines. So in this example, this is the input data, this is the TIN how it will create and this is the digital elevation model means raster here and this is how the 3D view will be there based on the digital elevation model.

But if I am having soft break lines that means my break lines are not very hard. Suppose, there is some geological feature which is going vertically downward like for example, a dike or a ridge or quartz reef then it depends whether if I am working from groundwater point of view then I would like to know whether there is any chance of flow of groundwater through that break line or that geological feature or not.

If I know by some means that it is impossible that water will flow across that ridge or a dike then I consider while creating a surface, I will go for option for hard break lines. But if I know by some means that the vertical feature or dike allows some water to flow then I would call as a soft break line. So that is why, similarly on the surface as well as in subsurface conditions, the prior knowledge is very much required.

And break lines can be even stream if I am working for some surface runoff modelling or other things then stream will play a very important role and this stream can become soft break lines as well as the hard break line. As you can see that different options, though input data is same but when soft break line and hard break line options are taken, the generation of digital elevation model, the generation of TIN as well as their 3D perspective views are completely different.

And, if you compare with no break lines all are. So, these options when you generate either raster or TIN, these options will be given to you while doing through some software. So, one has to be very careful and choosing the right option. And if you choose a soft break line or hard break line, you have to provide that file also where these poly-line file where these information is stored in the system because it is not just option is given. Once you have opted for this, it will ask a file. So, be ready for that file. The purpose here always to bring a more realistic picture, more close to the reality, more close to the nature. And that is why the concept of break lines have been introduce in GIS so, very-very important the break lines are. Now, what are the applications of TIN?

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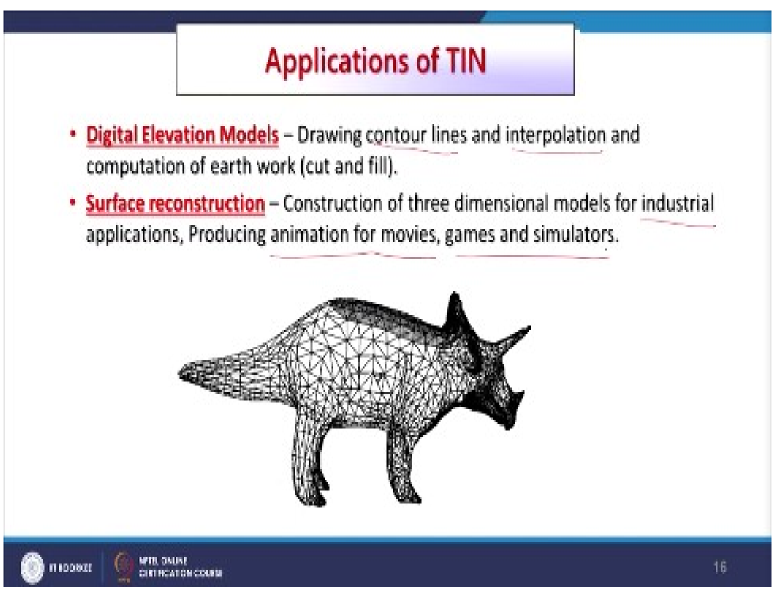

Various applications are there of course; you create these terrain surfaces and though the digital elevation model as you know the input can be controlled lines then through interpolations and we can go for earthen; this cut and fill analysis and there are n-number of derivatives which can drive from raster data. But however with the TIN, there may be some limitation on that.

And these 3 dimensional models can also be created using these surfaces either TIN or raster for various purposes; maybe for industries, maybe for animation movies, games, simulators. All those things, I will show you example like here this is the 3 dimensional TIN model of animal. Now, we do not have because these animals are extinct basically. So, whatever information is available if we want to reconstruct and see then first TIN is created then its artificial skin is dragged over this on computer and then you can rotate and see how this animal used to be there and how it was looking?

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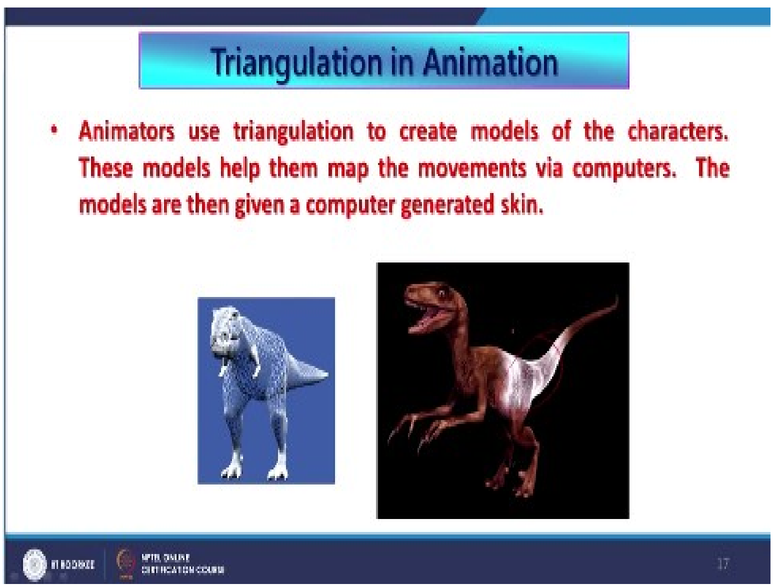

So these animations you know, in cartoon films or in scientific animations; a TIN is very popular model especially for 3 dimensional representations. Like here on the left side, you are having simple TIN which is bear without a skin cover. On the right side now, you are having a skin except for the middle part just to show you that how it is? So, animators use triangles or TIN model to create models of characters.

These characters maybe human characters or maybe animal characters and these models or some imaginary in many such animation of films and these models help them map the movements via computer. So, TIN is having application like in Earth Sciences, in civil engineering and hydrology and other places. And also they are having applications in animations also.

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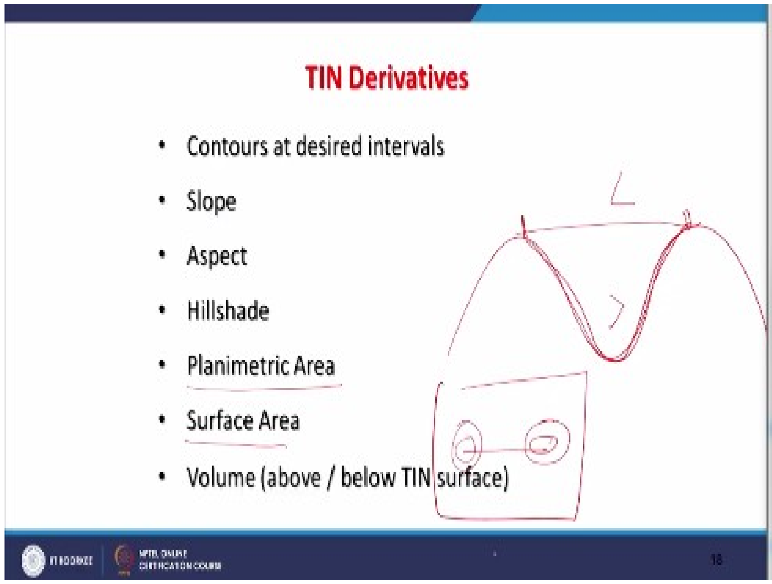

Now, what are the TIN derivatives? What are the things which we can derive from TIN? Of course contours; you can always drive because after all TIN is also formed using point data. The slope and aspect; these 2 parameters or 2 derivatives of a surface are simultaneously generated and then Hillshade can also be generated using your TIN model. And Planimetric area; this is very-2 important.

While calculating the area in a case of terrain that you can measure the planimetric area. There are 2 types of areas; one is planimetric area and another is surface area. Surface area for a hilly terrain is always more than planimetric area because surface area will measure along the slope and whereas planimetric area will measure only in the 2D plane. So, if I measure using a toposheet or a topographic map then I will have less area than the real one.

So if there are two hills and if I have to walk then I have to come down like this and go up. So that means my travelling time is much more but if I see on a map then these hillocks may be something like this. These are the contours. Now, I will measure like this. So that means I am measuring like this. So, this area is always going to be less than or length is going to be less than this one, is always going to be greater.

So that is why, the consequently also in case of when length is more in case of surface so, the area is also. So, whenever you are calculating area using a surface either TIN or digital elevation model, please represent the surface area not planimetry area because otherwise other estimations. Suppose now I am going for a road construction. So, in road construction, you would say that it is good, this much of length.

But when road construction will start then you have to do it something like this. So, complete wrong estimation and many-many civil engineering projects suffer because of these wrong estimations; either of area or volume or length. So, one has to be very-very careful while estimating or calculating length, area or volume because in cut and fill analysis. Where if suppose a road is to be made in any hilly terrain then which are the areas where the slopes will be cut in, which are the areas wherever you are having depressions will be filled. So that is called, cut and fill analysis. So, if you are having a correct measurement then only you can calculate very correctly. So, the planimetric area and surface area need to be understood very nicely.

Volume part; I have already said that cut and fill analysis about volume or below TIN surface that volume is calculated and it has to be very accurate for real projects.

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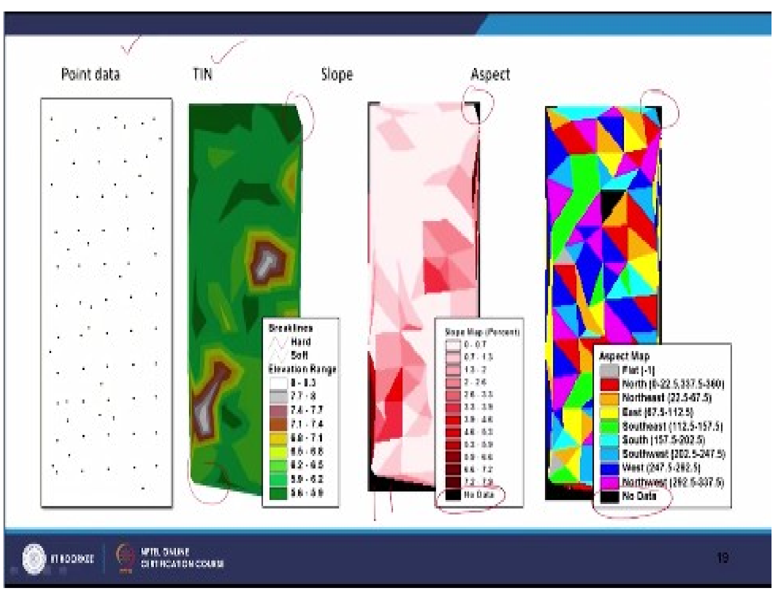

Now this one, I will be also showing using the same data set through the software and your output is going to be almost similar. So, this is the input point data. And using that point data, a TIN has been generated. Just notice what happens in case of margin or the boundary area. You do not have like here the distribution is this. So, as per the point of distribution on the edges, the same way, the TIN will be constructed.

And if I create a slope map from this TIN, I am going to have this but in the boundary area, I am having the black areas; no data basically. As you can also see that it has mentioned no data because on the margins or edges boundary, I do not have any triangle available because the input data was not there. And when input data is not there, the Boris Delaunay theorem cannot be satisfied and hence there will not be any construction of triangles.

And once the input TIN is having that problem then that problem will also be seen in slope as well as in aspect map and here also you see the no data. So, this is one of the limitations of the TIN.

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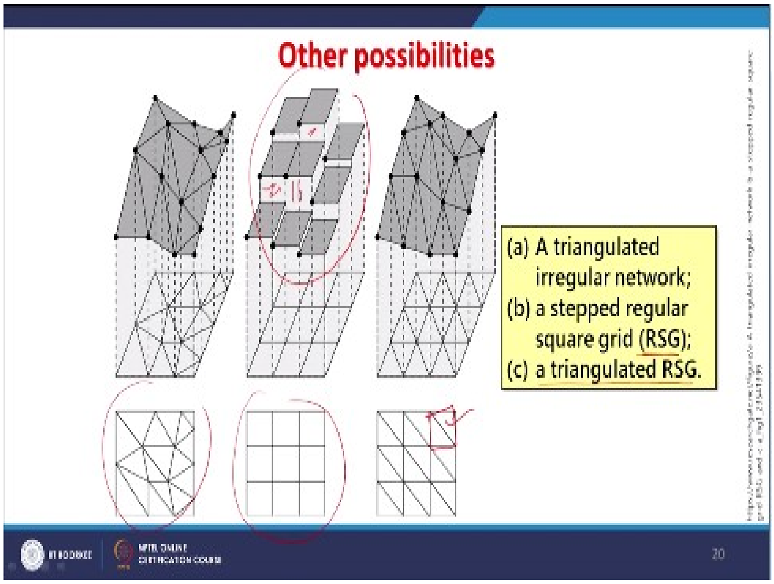

Also, this is what other possibilities is there that how you will handle in case of raster if ruggedness is there? This is how it will be represented as you can see here. But in case of TIN say continuous. So, this gap which you are seeing here is not seen in case of TIN because each facet will incorporate or take care about that gap. So, that is the biggest advantage.

How some recent development has taken place? And instead of a typical triangle, a stepped regular square grids (RSG) are used then sort of hybrid representation is possible, though a unit wise you are having triangles but 2 triangles are making a square and say continuous as you can see here. A better representation is possible but this RSG has not been implemented so far. I have not seen in any good software but very soon, this may be there.

However if we go for this, we are constraining triangles size and shape. So, indirectly we are going back towards the raster because the advantage with TIN is adaptable to relief roughness and therefore smaller or larger triangles can be formed depending on the roughness but if we go for this RSG model then everything is fixed. So that has to be again carefully evaluated before you go for this kind of evolution.

So, this brings to the end of this discussion about the TIN and raster and little bit comparison, I also did with the vector. One more point which I want to mention here that if I want to make a subset of raster or vector, I can do it very easily. I can use a polygon. Suppose I am having point distribution of all villages of India. Now I want to extract only for Uttarakhand. So I can use the boundary of Uttarakhand and can extract points for Uttarakhand.

So the subset; I can generate very easily. If I am having road network for entire India, I want to have a road map network for Uttarakhand. Same way, I can use the political boundary of Uttarakhand, I can take a subset and similarly if I am having raster data like a satellite image or a digital elevation model, I can use the same polygon for Uttarakhand and can extract that information.

But if my model or my data representation is through TIN, I cannot take subset because you have to think what would happen on the margins or the boundary of the TIN because by theory, it has to be triangle and if any system allows you to make a subset of TIN then on the boundary there will not be triangles. They may be rectangular or parallelogram and another issue are there which cannot be done and therefore subset of TIN is not possible so far, in any GIS software.

Now, what is the other way of doing? Direct method is not available. Though, subset creating through vector and raster as I have mentioned is possible weather it is a point data, poly-line data, polygon data or in case of your raster but for TIN, it is not possible. So, what is the way? Forward is that first because you know that TIN is formed from points, mass point. So, you take first a subset of mass points and then create TIN. There will not be any issue; still you will have a subset.

So, sometimes the literature may not mention but you are having software tools and you have to apply some techniques; some arrangements or some steps by which you can achieve almost same results. Thank you very much.