# Digital Elevation Models and Applications

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## Lecture – 09
## Triangulated Irregular Network (TIN) and its Derivatives

Hello everyone and welcome to ninth lecture on digital elevation models and application course, and in this particular topic we are going to discuss a triangulated irregular network; that is TIN and its derivatives. Earlier also I have referred this TIN, because this is another way of representing a surface. As we know that the digital elevation model is also one of the ways of representing a surface, so TIN is.

And it is not raster, because digital elevation model is a typical raster data structure, but TIN is a different data structure, and its like in a raster data structure we are having each unit is in a square in shape, but here each unit is in triangular in shape, but each triangle might be having different size and shapes. So, it definitely very much differ from a typical raster or digital elevation models, and we also drive, sometimes almost the same products as using a digital elevation model especially slope and aspect.

So, we will see what is basically exactly TIN is, and how these products, some of the derivatives can be derived using TIN model. So, as we know that two data structures to represent a surface, a rectangular grid or a elevation matrix, we also call them, and TIN which is a triangulated irregular network. This is based on a Delaunay triangulation concept which we will discuss very soon.

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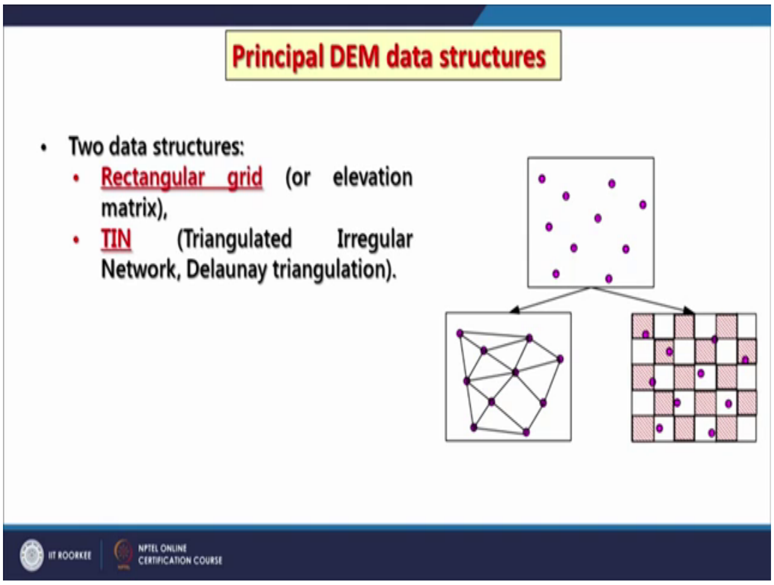


What basically the input data here in both the cases, whether you are going to create a raster for following the interpolation techniques or creating a TIN, the input data is a point data. As I shown here that a data is point data, we can create a raster of a say equal size of cells here, or we can also create TIN. As you can also see here that when creating a TIN then there are a network, irregular network of a triangles have been made and this area is representing the surface whereas, here the entire area or rectangular area is representing the surface.

So, this is one of the limitations which we will also see in case of TIN; that means that on the edges of the data, at the margins or boundary of the data the TIN is having limitations, but there are some advantages which we will see here. As we know that the regular grids or the typical raster or our digital elevation models may not be adopted to the complexity of the relief of the terrain. So, that an excessive number of data points is needed, to represent the terrain to a required level of accuracy.

What does it mean here is, basically that whenever a detailed a of terrain is required, the relief changes which are happening in a very small area, then in case of TIN a smaller triangles will be formed, and that relief or the complexity of the relief can be represented very easily. Whereas, in case of raster the cell size is fixed, and once the cell size is fixed then it does not matter what is the complexity of the relief. For a whole area the same cell size will be used, but in case of TIN wherever it is required it is adaptable to changes or adaptable to complexity of the terrain or relief.

So, wherever it is required to represent the terrain which is a complex, then a smaller triangles will be formed and wherever the terrain is flat, then large triangles will be formed. So, that is the adaptability of the TIN compared to our typical raster. So, triangulated regular network can be defined as a surface as I have already said that both digital elevation model; that is the raster is a surface so the TIN, they are represented derived from irregularly spaced points and break line features.

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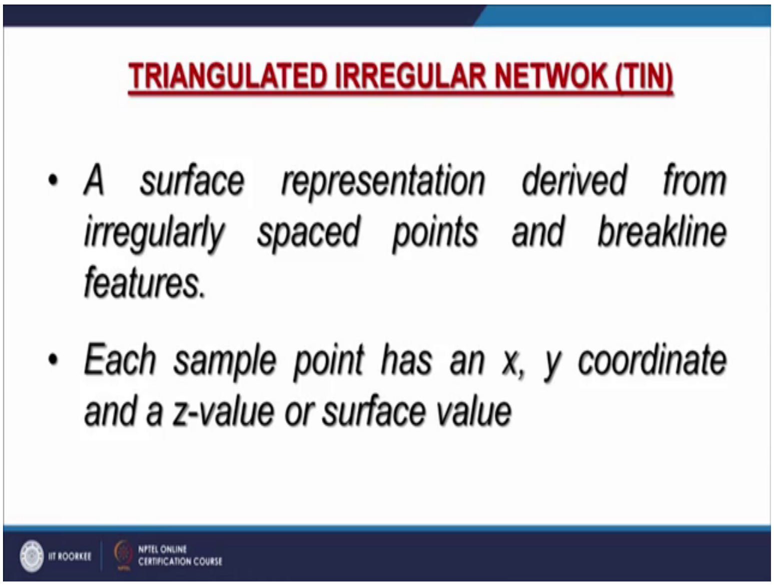


And of course, the data input is always in case of TIN is the point data. So, only from point data you can create a TIN, and each sample point or observation point for which we are having, may be having the elevation or some other values; like a pollutant value some concentrations and other things, then each point has an X Y coordinate and a Z value or the surface value, and that is why it is used as to represent the surface.

So, TIN model represents a surface as a set of contiguous none overlapping triangles, same as in case of raster also that each cell is a none overlapping. So, in case of TIN it is also contiguous and none overlapping triangles. Within each triangle the surface is represented by a plane.

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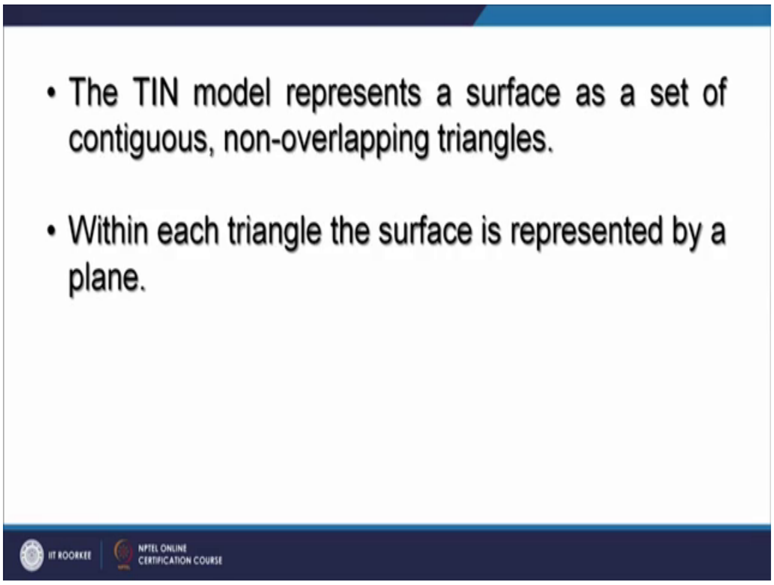


So, because this facet is a nothing, but a plane for each triangle and which forms the entire network. And the triangles are made from a set of points called mass points, the input is always from the point. So, the basis of this TIN is a given by a Russian Mathematician Boris Delone and it is also called Delaunay triangulation method

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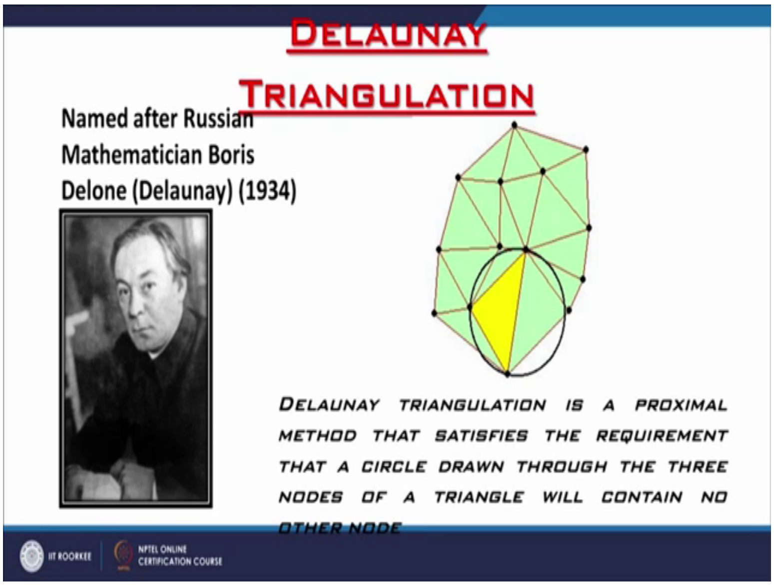


He gave this concept in 1934, and some way it is very simple concept that this Delaunay triangulation is a proximal method. So, that it benefits, it satisfies the requirement that is circle drawn through the three nodes or three input points, and there should not be any other node in between or any point here. For example, if a circle is drawn, passing through these three points one two and three, then no other triangle can be drawn within this circle. So, that is the Delaunay concept about this triangulation, and based on this, then entire network of a irregularly spaced triangles are formed. So, TIN sometimes you may find in literature that some people have put in along with the vector data structure.

So, but in my opinion it is incorrect, because it is not typical vector data structure, because vector data is a discrete data; whereas, raster data is a continuous data and TIN is also continuous. So, it is therefore, it does not fit as vector data, neither exactly it fit with the raster data, because in raster each cell is having the same size and shape, whereas, here each cell; that is triangle having different size and shape

So, that is why it cannot be considered as a typical vector or a typical raster, its a different system, neither we can say is a hybrid system. So, one is the vector data structure, another one is the raster data structure and third one we should consider TIN as a separate data structure, because the TIN represents the terrain surface as a set of interconnected triangular faces, and when we created TIN, there are four tables which are created and in the system that a node table, edge table, X Y coordinate table and Z table.

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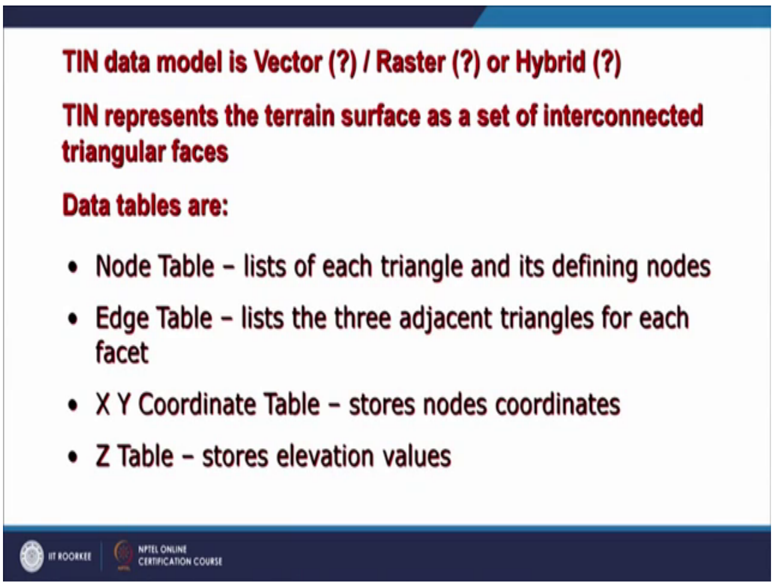


So, list of a like node table will have list of each triangle and its defining nodes. Whereas, edge table lists the three adjacent triangles for each facet, and X Y coordinate table will store of course, the node coordinates and Z table, it will store either elevation value or some other value may be pollutants value and p h value or some other thing. Let us see the example; example here is, that they, there are these data inputs are shown numbered had been between 1 to 11, and there 4 tables as mentioned that you are having node tables.

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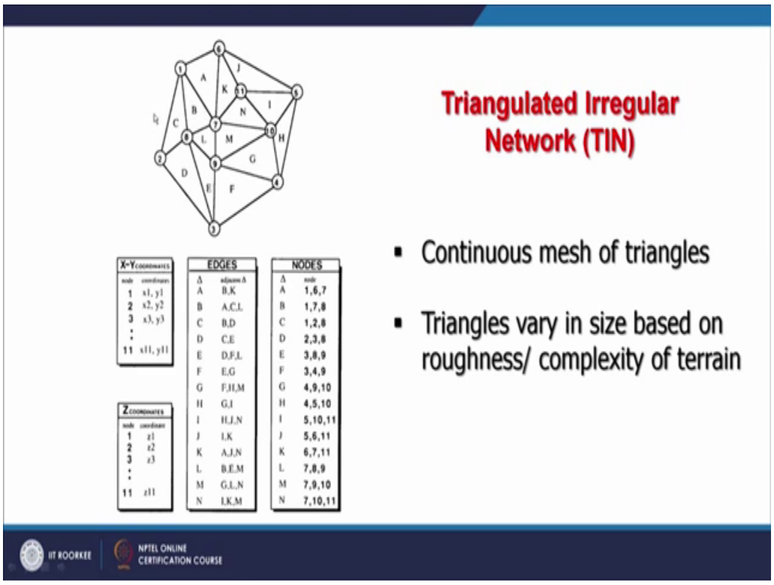


So, each node will have like here, if I say this is for the triangle A. So, then there are it is triangle A is formed by 3 nodes. So, 1 6 and 7, here 1 6 7, let us take another example like a triangle F, triangle F is formed by 3 nodes; 3 4 and 9. So, triangle F is formed by 3 4 9. Similarly we will have the edge nodes, a edge table which will store this information. So, for triangle A, the edges are B and K who are on the sides.

Whereas for a say example triangle F the edges are E and G; similarly we will have an X Y coordinate table and Z table for all these triangles which are representing these 11 input points. So, it is a continuous mess of triangles like your typical raster which is also a continuous data, but it is having problems at the edges. As we are seeing again and again even in this example, if we would have created using these 11 points which are distributed in this space, then within these points, observation points, input point we would have interpolations.

But on the other side we would have extrapolation as discussed in the lecture in which we have discussed the spatial interpolation techniques, but on the edges or beyond these observations, we will have a extrapolation in case of raster, but here no construction of any TIN, because you do not have and it does not satisfy and the Delaunay concept. So, therefore, on the edges always you will have a problem. Another problem with a TIN we will be faced that we cannot create a subset of TIN. Once a TIN for input data points have been created, now we cannot make a subset of TIN. Whereas, when we have been discussing the digital elevation model our concept of digital elevation model, this has come that a subset of a digital elevation model can be created, this will be elaborated in subsequent lectures also.

So, there are some is advantages and disadvantages with both TIN and raster, and because the TIN varies its sizes. So, the triangles vary in sizes based on roughness or complexity of terrain. So, it adopts the complexity of terrain very easily; whereas, raster is incapable of doing thing. And it depends on wherever if a terrain is flat then large triangles are formed, if terrain is having lot of undulation high ruggedness then small triangles will be formed.

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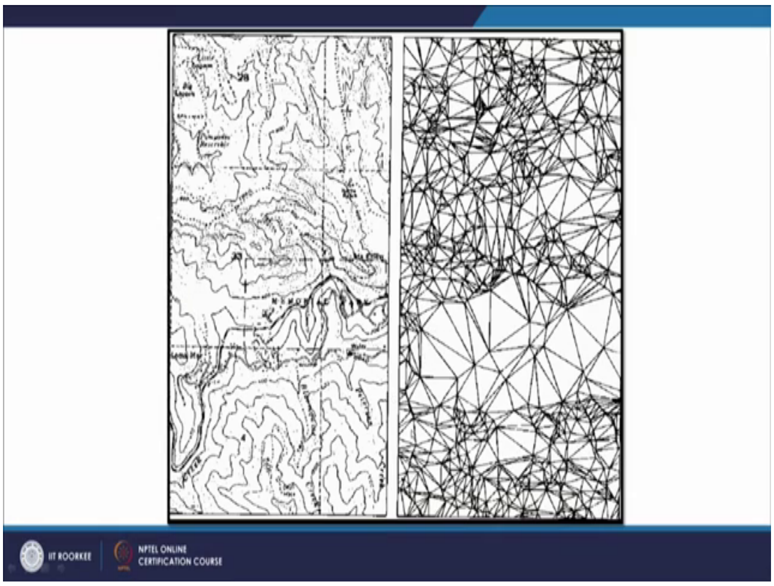

The real example shown here that a on the left side we are having a contour map, and wherever we find the contours are very closely spaced in corresponding TIN model we are seeing a small triangles like here. And wherever we find that the contours are very far away, in these areas we are seeing triangles which are large here. So, this is the biggest advantage with TIN, or one of the advantages with TIN, that it adopts to the complexity of the terrain. Whereas in case of raster there is a fixed size of the cell and shape as well.

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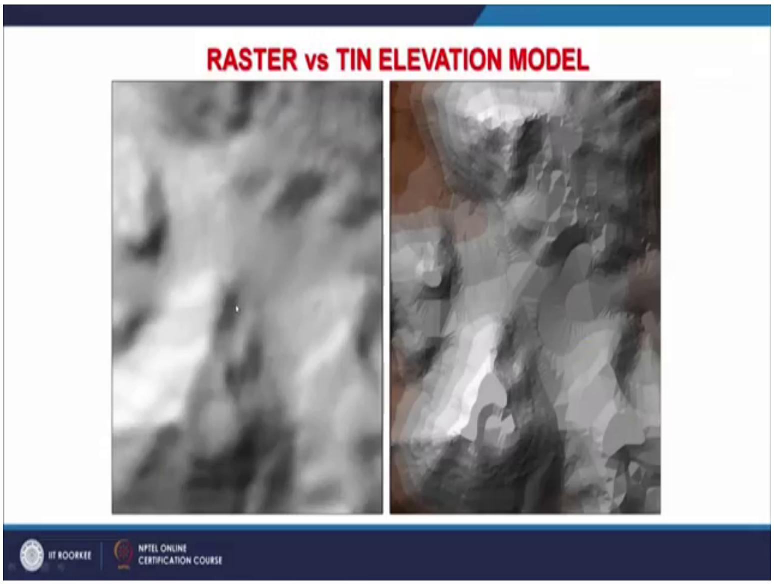


In also one example that here this is the typical raster has been created using the same data sets and a corresponding TIN using the same data set has also been created. As you can see that, because it is adoptable to terrain complexity and therefore, when we display, you can visualize that the terrain looks much better in convincing as well.

Now, so we reach to this discussion on all advantages associated with TIN, that terrain parameters; like slope and aspect calculated for each triangle and stored as an attribute of the facet. That means that whenever we create a TIN from input data points, then at the same time these two derivatives are also created; where as in case of raster we have to further derive these two products.

So, in case of TIN they are simultaneously created. For areas of complex relief, TIN works better than raster. So, if somebody is working a terrain like Himalaya, then raster may not be adoptable to the complexity; whereas, TIN is, and therefore, such rugged terrain like Himalaya can be represented very nicely using TIN model. More detailed representation for higher density of data points.

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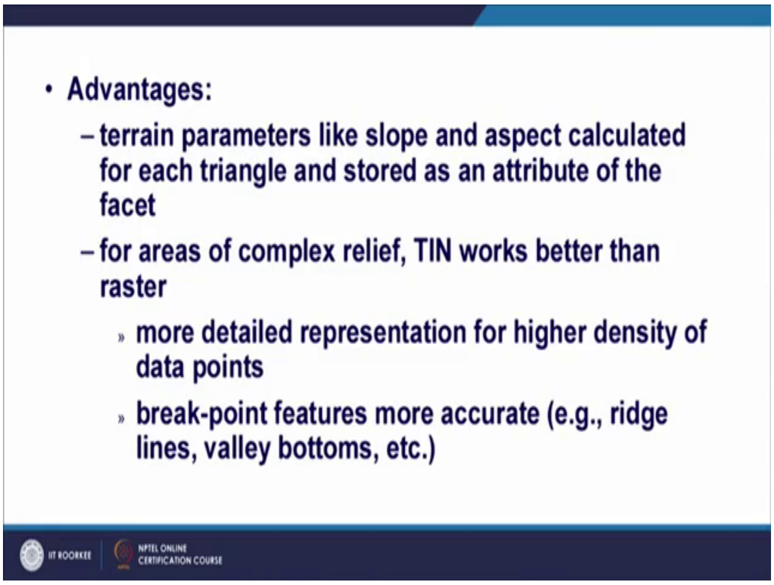


So, if you are having, because these observation points or data points are never uniformly distributed. So, the advantage with the TIN wherever you have the more density of points, better representation can happen, but not in case of raster, because the cells size and shape is fixed throughout one set of raster, and break point features more accurately represented in the TIN. Break point features can be ridges or valley bottoms or some geological structures like folds and other things. So, these features are also very nicely represented in TIN rather than in raster. As mentioned there are advantages so disadvantages with TIN.

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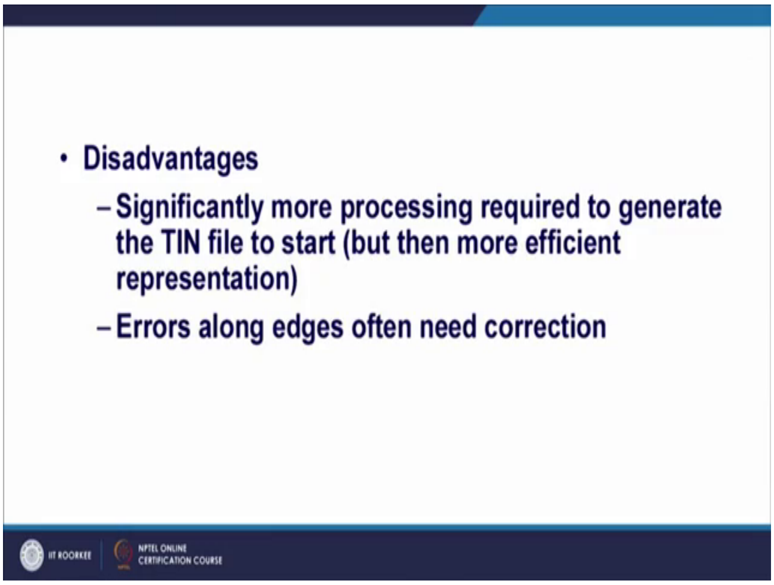

The disadvantage is that the significantly more processing is required to generate TIN, compared to raster data, because raster data is a very simple data and therefore, generating raster data becomes relatively faster as compared to TIN, and errors along edges often need correction and that is the problem with the TIN that on the margins of your dataset. There might be some errors, or it does not complete the area.

So, if somebody would like to have, you know a subset of the TIN, then it has to create again the TIN taking the selected points. So, that is one problem, and a subset of the; once the TIN has been created then subset cannot be created, whereas, in case of a raster or digital elevation model, subsets can be created very easily.

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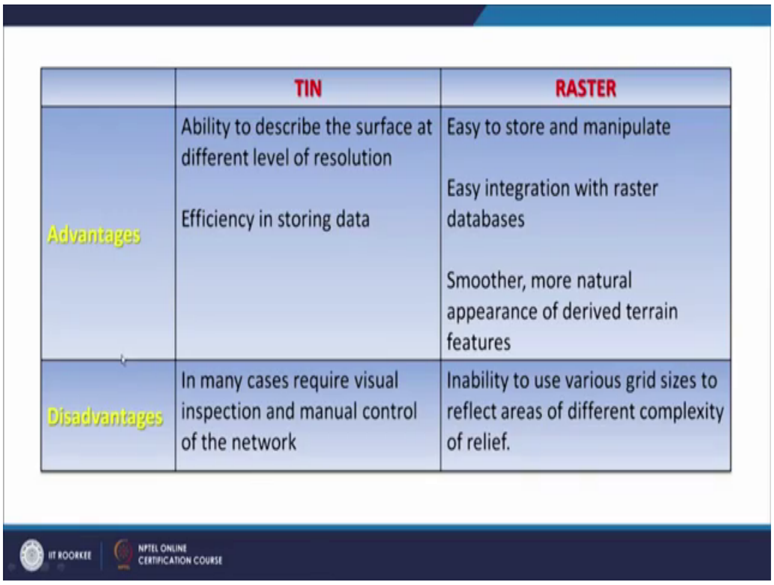

| | TIN | RASTER |
|---|---|---|
| Advantages | Ability to describe the surface at different level of resolution<br><br>Efficiency in storing data | Easy to store and manipulate<br><br>Easy integration with raster databases<br><br>Smoother, more natural appearance of derived terrain features |
| Disadvantages | In many cases require visual inspection and manual control of the network | Inability to use various grid sizes to reflect areas of different complexity of relief. |

So, let us compare now one to one that advantages and disadvantages that TIN has a ability to describe the surface at different levels of resolution, and whereas, in case of raster easy to store and manipulate, because it is a simple data structure, and it is easy integration with raster databases. This point I want to elaborate further on this, that because lot of other data sets also comes in form of raster data; like for example, satellite images. Satellite images are also raster, so TIN is agreed raster; whereas, satellite image is a raster image and therefore, the integration as we have seen also in earlier lectures, that the integration of a satellite images with digital elevation model becomes very easy.

whereas, integration of digital elevation model with satellite images is quite difficult, because the reason is the both data structures are completely different. This TIN is, because it is stored in form of tables. So, it is storing efficiency is efficient in case of TIN, but also raster in that case is, not difficult because it is a simple data structure. Raster is smoother looks more natural appearance or derived terrain features, and the features and might be slope aspect or drainage network.

And other things, but in case of TIN two main features are derived, or generated at the time of construction of TIN, but later on once we move forward and along with the TIN we find sometimes difficult, because not lot many derivatives can be derived from using TIN, whereas, lot many derivatives can be derived; that is why it is said that the D E M is a storehouse of information, but not the typical TIN, but still it represents the slope and aspect in a much better and accurate way as compared to our digital elevation model.

And disadvantages in many cases, it requires the visual inspection and manual control of the network. Whereas, in case of raster inability to use various grid sizes to reflect, because within one data set the cell size and shape have to be same throughout. And this is the example that we are having the data without any break line. So, this is how it can be represented in form of TIN in a typical digital elevation model it would be represented and we can create also 3D view like this.

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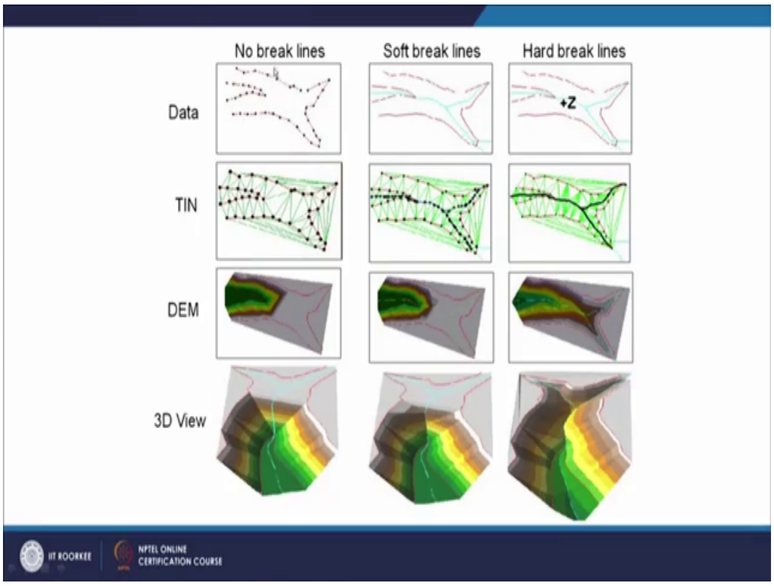


But if we are having soft break lines, then soft brake lines may be a drainage network which we consider as a soft break line, and the same way a 3 D perspective view can be created, TIN can be created, it becomes further complex as compared to the with no break lines, and then we see a corresponding digital elevation model as well. Because while creating digital elevation models, break lines can also be incorporated, using not all an interpolation technique.

But a few interpolation techniques, and like; then the when we are having hard break lines, may be some geological structures and other things, and or maybe some dikes or reefs quads reefs and so on, then that representation of these hard break lines becomes much more complex in case of TIN has one can see, D E M also becomes much more complex as compared to no break lines and this is how the 3 in 3D view it will appear. So, a break lines, because TIN incorporates break line. So, it is easier to handle be break lines in case of TIN.

But in case of raster only two interpolation techniques allow us to use the break line. There are a lot of many applications of TIN, especially like a creating a surface, driving slope and aspect, maybe 3D perspective view and so on so forth, but TIN is also used for many animations and other things which we will see some examples.

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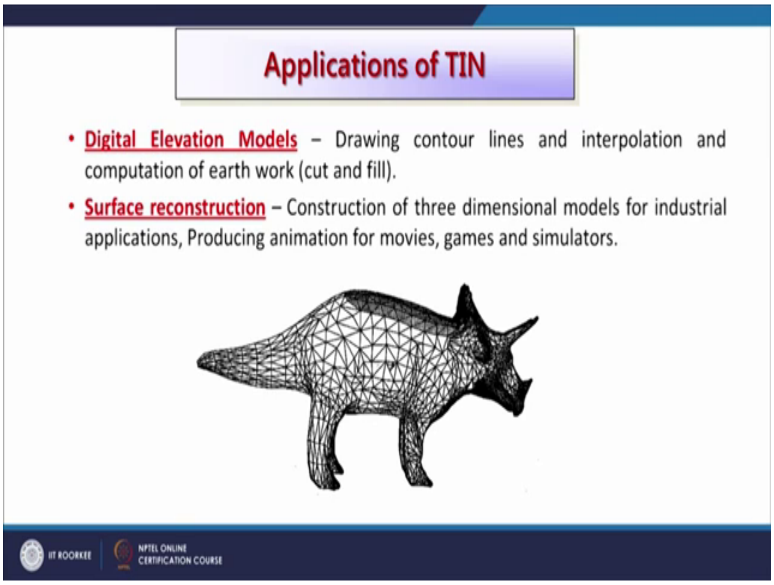


So, digital elevation models which are drawing from contour lines or in and through interpolations, and a can be used for various works including like cut and fill analysis and this, a surface reconstructions and construction of three dimensional models for industrial applications maybe producing any animations for movies, games and simulators. And for example, if I have to represent this animal, then it is easy to create a

3 D view of this animal or 3 D wire mesh structure of this animal using TIN model and then some texture of the skin of this animal can be draped over it to visualize that it is close to the natural one.

Because as you can see here that in this front part of the mouth part, it is having very complex say representation and therefore, small triangles have been formed here, but near the stomach part, the surface is not that undulated and therefore, now it is represented through large triangles, because that is the one of the biggest advantage of TIN is that it is adaptability, it is adaptable to complexity of the surface.

This TIN is used extensively in animations, and a to create the models of characters, and these models help them map the movement via computers, because a you know the movement can also be incorporated with this TIN models of animals or any other structures, and therefore, they are extensively used in animations, and these models are then given a computer generated skin and they look something like this.

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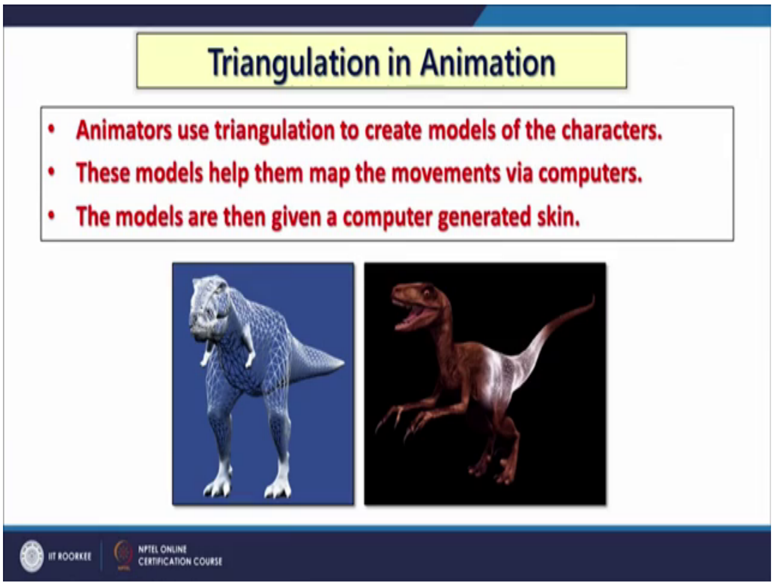


So, a 3D models for animations can be created very easily with animation, with the TIN models, but raster data structures cannot be used here in that way. So, what are the TIN derivatives, we have discussed to some extent, but anyway, that contours at desired intervals can be created of course, a slope and aspect, these are the simultaneously created when we create the TIN itself and the hill shade can also be, it is generated also at the same time.

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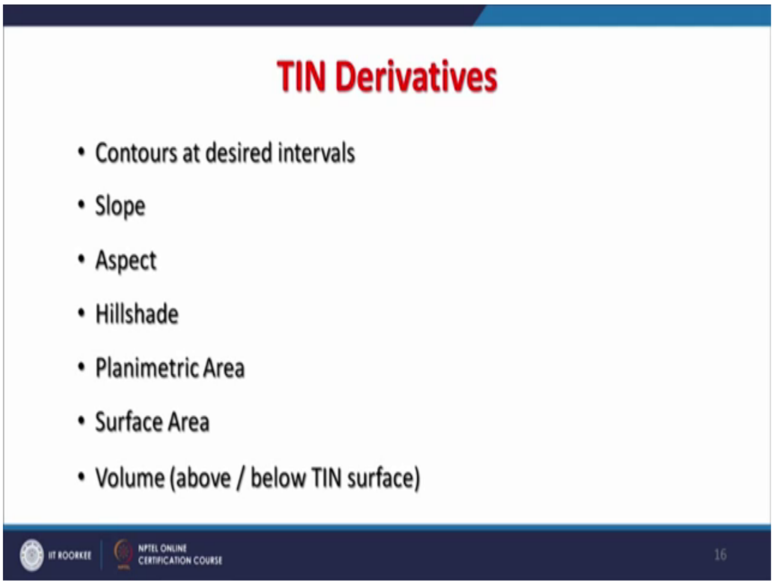


And the planimetric area can also be calculated, and a surface area can also be calculated, volume above or TIN below TIN surface can also be created. So, many derivatives are possible, are also possible with the TIN model. Here are the some examples that our, the data set is this one, the point data.

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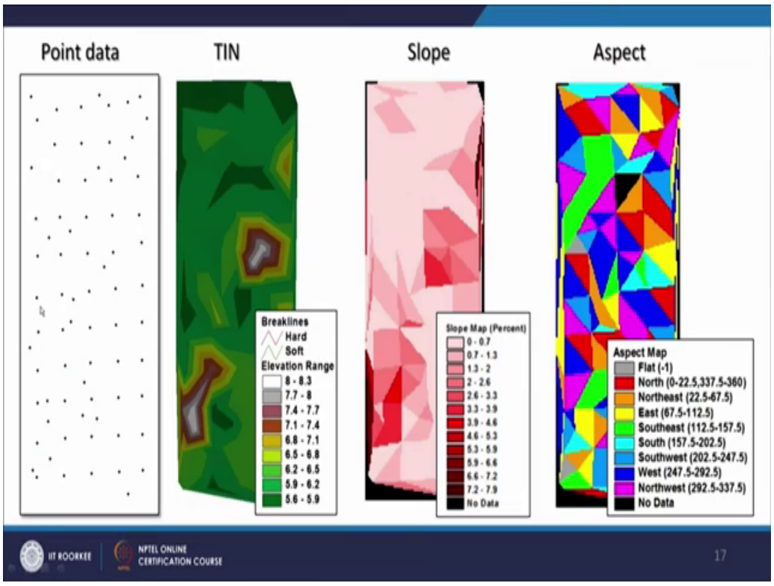


As have been mentioned that a TIN can only be created using point data, and a when this point data is used to create a TIN this is how it looks, and these ranges have been then classified here to represent through different colors, then you can derive slope map.

You can also derive the aspect map. As these two derivatives are also possible with the digital, typical digital elevation model or raster digital elevation model and this bring to the end of this discussion about a TIN surface. The important thing which I have also mentioned in this lecture is that the TIN is adaptable to the complexity of the terrain whereas, raster is not.

The problem with the TIN is, that a though we can create TIN quite easily and the software's which we use, they are all supporting generation of TIN models, but the TIN cannot be carried forward for long, because it does not fits very well with other raster datasets, because raster datasets are very common datasets one, and lot of raster datasets are available free of cost. For example, digital elevation models, for example, satellite images; whereas, TINs are not available free of cost.

So, that becomes one more complexity with the TIN, that later on we have to convert our TIN models into raster to proceed further, but if somebody is looking only up to say slope and aspect and some simple derivatives, and in that project the requirements are not for like surface side logic modeling or some other things, then TIN is the best available solution to represent the surface and these derivatives.

Thank you very much.