Higher Surveying
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Module - 7
LiDAR (LiDAR grammetry)
Lecture – 26
Information Extraction from LiDAR Data

Hello everyone, welcome back in the course of Higher Surveying, today we are in lecture 4 of module 7 ok. In the same module in the last 3 lectures we have learned many things. The first thing was: what are the fundamental principles of the laser and how laser can be used in order to determine the time of flight and distance and so on.

So, basically we said that we can determine the range over a large distance say some kilometres, 1 kilometre or so. Fine, using that information in the next lecture we learn that how to configure various sensors for example, GPS, IMU and laser scanner in order to acquire the 3 D data of the terrain; using air bun platform or terrestrial platform. In lecture 3 we have learned that once we acquire the data it is acquired in the form of swath.

So, there are each swath is there are for per flight line; that means, one flight is leading to one swath and swath is a distance perpendicular to the flight line. And, since we have the overlap so, using the information from GPS: that is trajectory of aircraft and the IMU that is the roll pitch and yaw of the aircraft position at different different location on the aircraft trajectory. And the laser scanner data that is the scan angle and the range for each pulse we learnt how to do geo location process in order to georeference the complete 3 D data into the 1 international, 1 reference plain. Now, we have learnt that how to acquire the data in one global reference frame.

Fine, so, let us say that we have a LiDAR data which is completely geo referenced as well as the data has only random errors, no systematic errors is there and now I can use this data for generating different different 3 D products. So, in this lecture we are going to talk about how to extract the information from the LiDAR data right. So, this is our lecture 4 on information extraction using LiDAR data.

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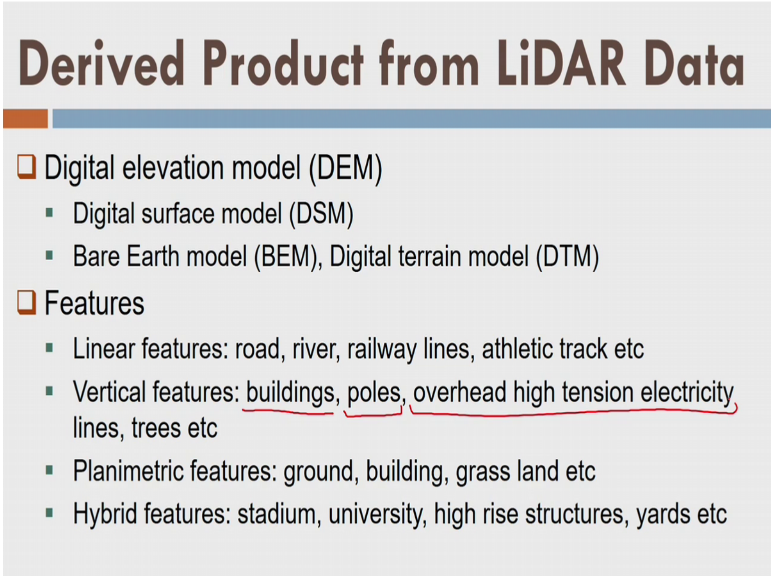

And what are the possible products? So, first I would like to say that the data once you acquired in by the LiDAR and it is geo referenced by direct geo referencing method what we call geo location then that data represents the complete surface of earth in the given area of interest right. So, I can say that if there is a tree, I will have the surface of the treat expressed by the LiDAR data if I have the tree then I can have multiple returns also.

So, I have different layers of the tree on the other hand if I have the building data then building rooftop will be there, data is also there of the building sites. And similarly, if I have a terrain or open ground I will have the data of the terrain and each data is subjected to some random errors, but the data is still a point data is still not rectangular grids. Now, what are the possible products that I can make from the this data? The first product is my digital elevation model and second product is digital terrain model moreover I can also prepare digital surface model.

So, what is the difference between the 3 terms? Ok, if I have the delta and delta is representing the complete and actual surface of the earth that includes all the natural as well as a man made structure for example, tree, buildings and terrain everything is there. So, that it is called digital surface model because it is representing the real surface of the earth.

What is it is today? So, what how my earth on the area of interest look like. So, it is DSM is representing that actually ok. What about the digital elevation model? Digital elevation model is very generic term that we use in order to specify the 3 D data in the form of grids. So, each is grid is having x, y and z where z is the height of the grid and x and y is the planimetric position of the centre of the grid. So, this is what we call DEM, a generic term.

Now, what about DTM? If you consider some dynamic structures for example, trees and the buildings, buildings are manmade structure or artificial structure. However, trees are dynamic structure in a sense they grow with time and so, this structures are natural structure. Or maybe if I talk about some kind of small pit on the surface small pit could be of any size, but we know that it is not part of the natural terrain.

So, all these features if I remove from the DSM then I will get the DTM, what we call digital terrain model. So, and what is the importance of DTM? For very large scale study for example, mega floods like tsunami rather we want to have the terrain surface, that is more important to us not individual building or individual trees important.

On the other hand if you look in to the urban area, urban areas if they are thickly populated by the buildings we have very important thing here that we cannot ignore the buildings, in that case we need to have the digital surface model. So, in those cases digital surface model is more important than DTM ok. So, now having understood the DSM, DEM, DTM. So, I can extract the buildings also.

So, now in this lecture we are going to talk about building extraction, digital elevation model development and digital terrain model development using LiDAR data ok. So, let us start that what are the features we have linear features like road, river, railway lines, athletic track etcetera. They are more elongated now we have vertical features for example, buildings; that means, they are growing more in the vertical direction compared to the horizontal direction.

Then we have poles, electric poles or maybe telephone poles or then we have overhead high tension electricity wires or lines, then we have trees also. So, these are vertical features, then we have planimetric features for example, a playground maybe a building which has less height compared to its horizontal dimensions, then we have grassland and so on ok.

What are the hybrid features? Hybrid features means the places which has both vertical as well as horizontal features for example stadium, stadium has very high huge building at the same time it has very large ground right, then we have the university campus such things are classified in the hybrid features ok. So, using LiDAR data now we want to look into the various feature extraction as well as the basic model that is digital elevation model and digital terrain model extraction. So, let us go head ok.

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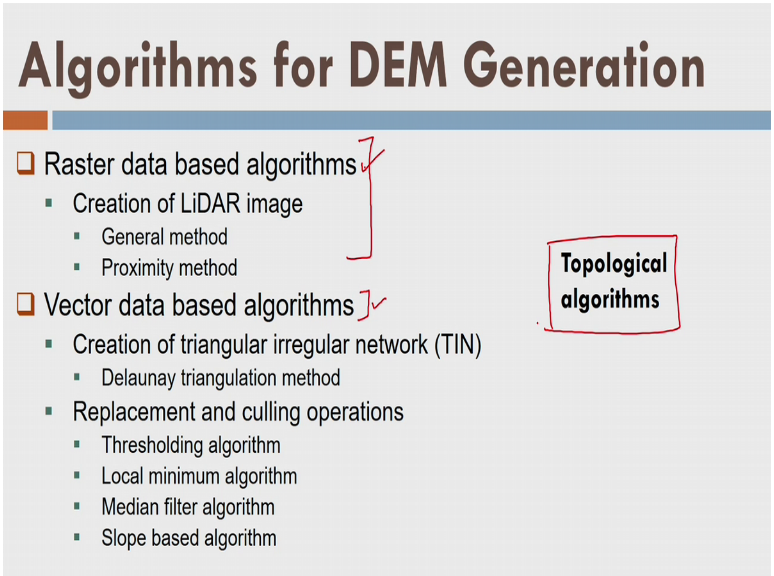

So, now in case of LiDAR we know that it is a point data and also it is not regularly placed or it is not uniformly placed right. So, if I want to prepare the digital elevation model or digital terrain model using LiDAR data I need to consider some algorithms, it is ok. So, there are 2 types of algorithms I can mark here, the first is the raster based algorithms or raster data based algorithms and then we have second type is vector data based algorithms ok.

We can use any of these algorithms in order to create the digital elevation model. All this algorithms are in the category of topological algorithms and topology is nothing, but the relationship of one point with it is neighbourhood.

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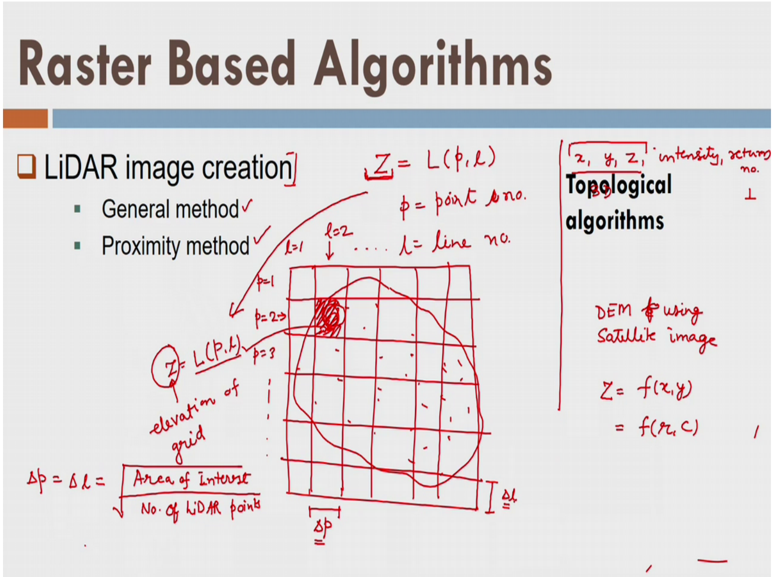

So, let us talk about the raster based algorithms or what we the raster based algorithm for the digital elevation model preparation using LiDAR data. Now, we have to create the LiDAR image ok. LiDAR image is written as Z is equal to L indicating LiDAR and p coma l, where p is my point number and l is my line number. So, which line I am referring to and which point I am in that line I am referring to. So, what is the elevation of the point? Ok, before that we should also know one thing that finally, I will get this information x, y, z, 3 D coordinates then we have intensity information.

And then we have the return number, remember in case of multiple return I have maybe second return third return and so, on. So, we have data with us and I want to utilize this data only and using the first return only remember. Why because we are working on the top of this structure for example, building top on big tree top on big terrain top whatever. So, we want to use this x, y, z data with this 3 D and we want to develop the various products like digital elevation model or DTM or maybe you want to extract the building information.

So, I am saying that let us express my LiDAR data in the image form. So, what does it mean? So, given the data let us say this is my area of interest and this is the data given which is a randomly distributed LiDAR data. So, what we suggest here is let us develop image or what we call as LiDAR image and divide this image into the grids like this.

So, these are my square grids fine ok. So, this patellar pixel for example, here it is represented by Z is equal to L p l which is written here. What is that? Z is the elevation of the grid ok. You can understand the similarity between the digital elevation model from satellite image, how do we express it? May be drone image we say that Z is equal to function of x y right ok.

So, here sometimes we also write the function of row and column. So, instead of this thing I am representing my this location by p and l. Now, I want to find out what is the value of the Z at a given location p l; that means, what is the value of Z for this pixel here ok. So, what are the methods that I can use in order to extract this information of Z using the LiDAR data?

So that once I have filled the Z data for all the grids I will have the digital elevation model. So, we have 2 methods, one is the general method and one is proximity method. Proximity methods are basically coming from the photo grammetry or we can say from the image processing. So, let us look in to the proximity method first.

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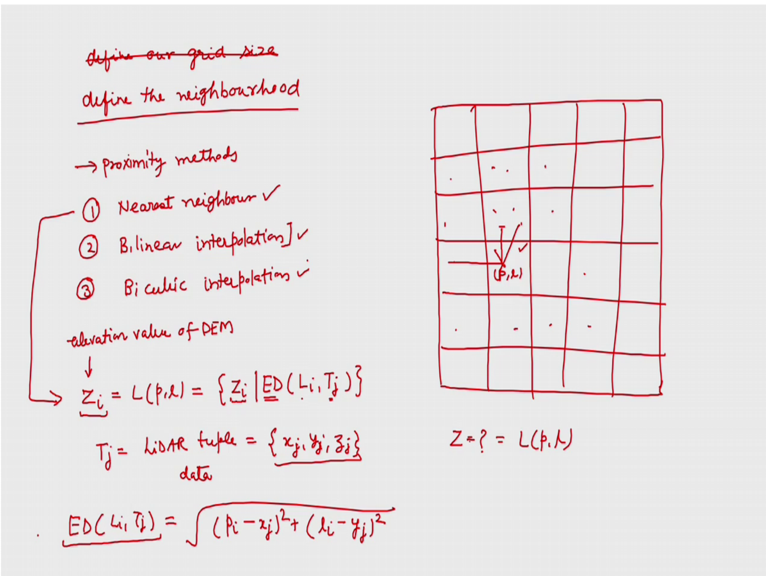

So, first of all we define our grid size right. So, what do you mean by grid size here? Ok so, first before going into these methods we have to have our grid size define; that means, this is my grid size here and this is the grid size in the y direction here. Let us call it delta l and that is call as delta p.

So, I can say that delta p and delta l both are equal. So, I am having a square grid and this is given by the area of interest divided by number of LiDAR points. I have calculate the delta p value and delta l value and then I have develop this grid and over laid on the given LiDAR data ok. The next step is define the neighbourhood ok.

So, that we can use either proximity method or we can use the general method right. First talk about the proximity method. What are the proximity method? There are 3 proximity methods, one is the nearest neighbour, second is by linear interpolation. And we already know that we have done this thing in the photo grammetry and then by cubic interpolation ok. Since, we have already discussed about bi linear interpolation in photo grammetry, I am only going to discuss about the nearest neighbour here ok. So, let us see this is my grid and.

Fine, so, let us say this my p l, there I want to fill the z value; that means, what is a Z? Given L p l; so, in case of nearest neighbour method I will consider the nearest neighbour or the point which is located nearest to that p l location. So, p l is nothing, but the central location here and let us say that some point located here randomly this way, this way may be here also here like that.

So, these are all LiDAR points they are falling in this grids. Now, what will I do? I will take the points which are around the p l and try to find out the Euclidean distance from this point, this point, this point and so, on like this point ok. And then we say that the point which is nearest to the p l location we will assign to this grid right.

So, we have seen that we have define the nearest neighbour and we are assigned the z value fine. So, remaining 2 methods like bi linear interpolation and bi cubic interpolation you can find it yourself right. Now we have the general method.

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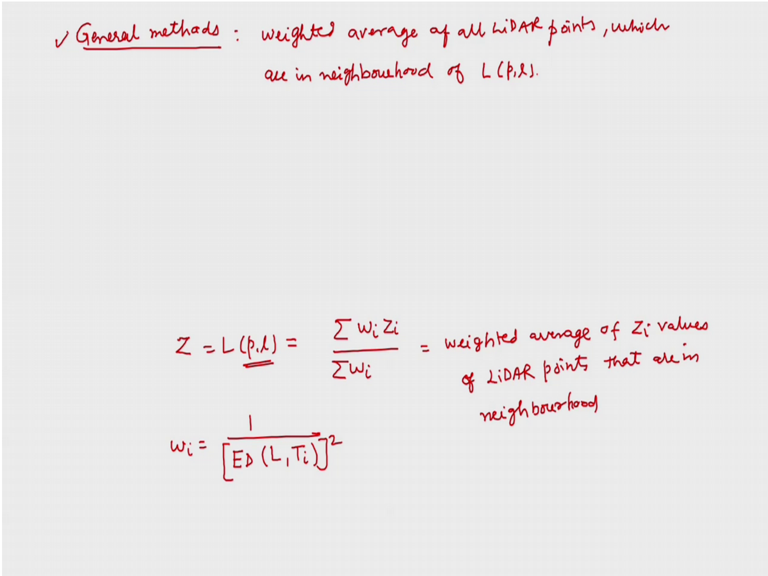

So, in case of general method we take the weighted average of all LiDAR points which are in neighbourhood. Now, how to calculate these Z value? And that is nothing, but the weight i Z i divided by W i sigma. So, that is my weighted average of Z i values of LiDAR points that are in neighbourhood. And we have already defined the neighbourhood fine.

So, how to define the weight? So, weight is nothing, but the inversely proportional to the Euclidean distance square. I can say here the Euclidean distance between the point l and T i right. So, once you define that i number of points or n number of points which I am indexing by the i one by one.

So, the Euclidean distance is this much and if I make the square of this distance; so, this is my weight; that means, higher the distance from the candidate pixel p l or l right to a point T i a which say that I will give less weightage to that and finally, by this way I will calculate the weighted average right. So, this is what you call the general method ok. So, these 2 basically methods are the raster based methods where we have a grid and you want to fill that data on the grid.

So, let us say by these methods we have prepared our digital elevation model ok. What about the other method? The LiDAR data is a point data. So, I can develop some kind of vector based algorithms also fine.

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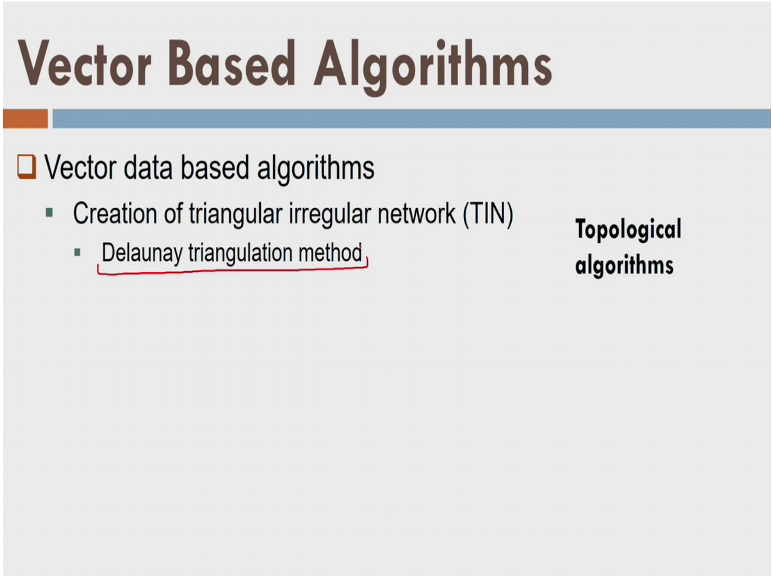

Let us talk about the vector based algorithms. So, vector based algorithms are basically based on the Delaunay triangulation method ok. So, let us look into the Delaunay triangulation first.

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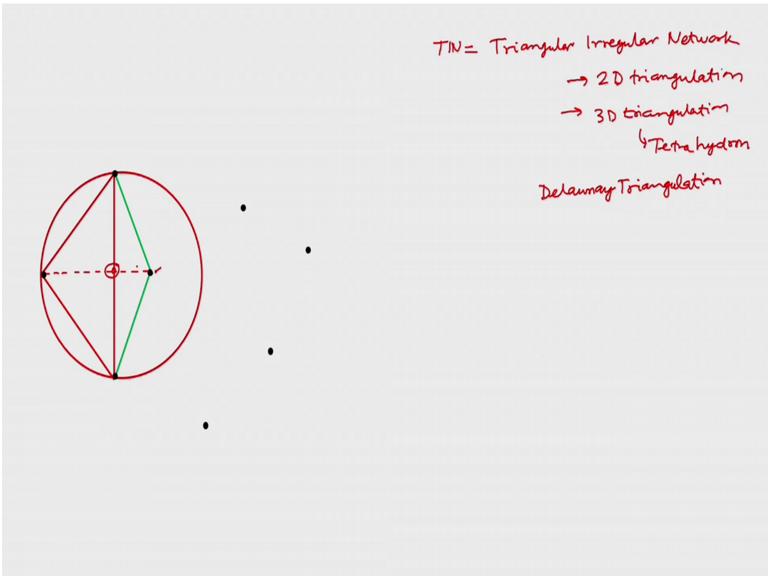

And let us see there are few points these are my LiDAR points so, each points are representing LiDAR point. Here, using these points I am going to develop the triangles and I want to develop some kind of triangulation scheme where each triangle will represent certain area. So, that way what we call as 2 D triangulation or we have triangular irregular network that you want to develop. So, we have 2 D triangulation scheme, we have 3 D triangulation also. So, this is called a tetrahedron ok. So, now, issues that how to develop this triangulation scheme or what we call here is TIN right. So, let us look into the data which is this way. So, these data this black dots are specifying the LiDAR data fine a method is Delaunan triangulation.

So, let us look how to develop the Delaunay triangulation. So, first you take any 3 points and develop a triangle. Now, you will fit a circle that is circumscribing circle passing through these 3 points of the triangle like this ok. So, now, you realise that within this circle there is another point falling here you can see here ok. So, that is not an appropriate condition for this Delaunay triangulation. So, what we will do ok.

If you develop a triangle then it there will be 2 triangles in one circle that we do not want. So, what will we do now we will (Refer Time: 19:48) diagonals of the 2 triangles or we can say quadrangle ok. So, what will I do here I will remove this diagonal and I will develop this diagonal right and by this way I will create 2 triangles. So, let us see I remove the diagonal.

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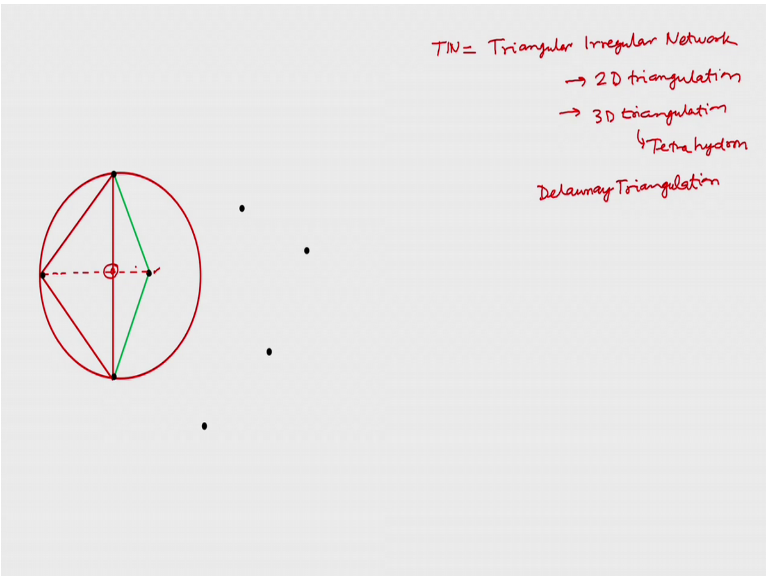

And I created another diagonal and that is what we call the diagonal swapping fine ok. So, you learned that how to do the swapping of diagonal now, let us fit the circle again to this triangle the purple triangle and the yellow triangle. So, like this now I can see in each of the circle there is no force point in line let us take one more point.

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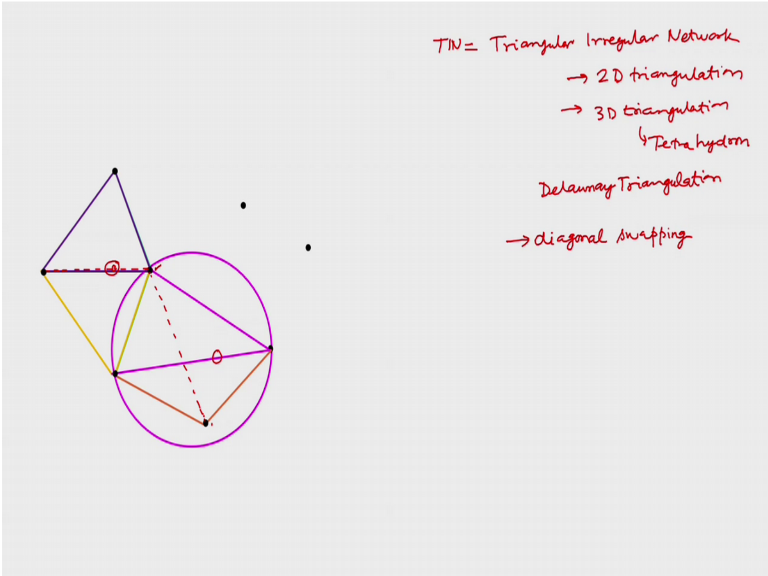

So, let us say this point I have developed a triangle here and again fit a circle like this and again we can see that this point is falling inside ok, again we have to do the diagonal swapping. So, let us this is my new triangle and 2 triangles are falling in one circle. So, what will I do? I will remove this diagonal and I will create this diagonal like this and like this so.

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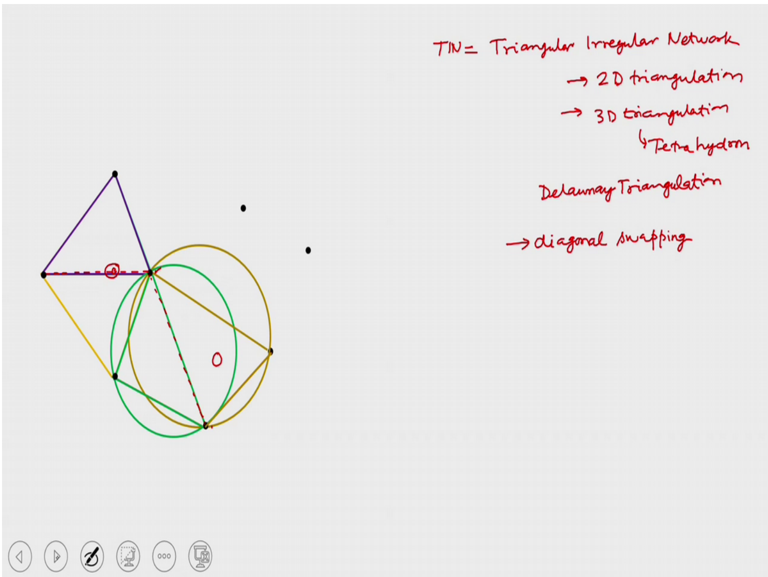

I got 2 triangles from the quadrangle ok, let us fit this circles again for this green triangle and the another triangle. So, I get again 2 circles and each circle contains only 3 points on it is circumference. So, this is the process called Delaunay triangulation by diagonal swapping method right. So, let us consider 2 more points right.

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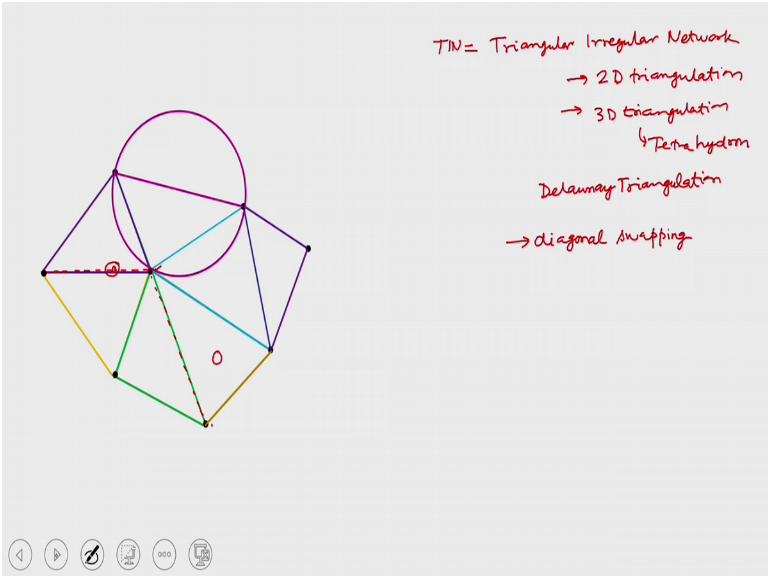

So, let us develop this way and try to fit a circle through these 3 points. Now, I see that there is no point which is falling inside the circle. So, that is acceptable triangle to me ok. Fine, what about the last point? The last point is this that I will connect.

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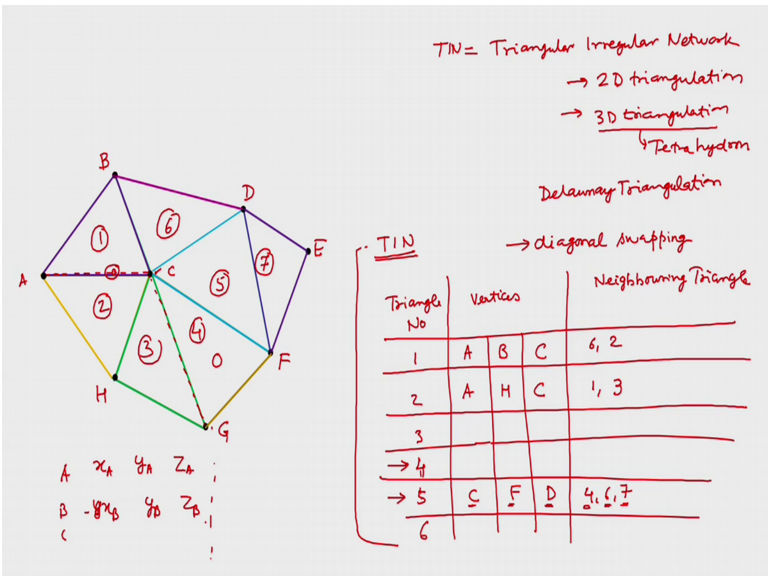

And this is the triangular irregular network using diagonal swapping method; if I number these triangles 1, 2, 3, 4, 5, 6 and 7. So, how to store this data? Or how the triangular irregular network store the data? Ok, let us see if I talk about the triangle. So, this is my triangle number here, I will put all the triangle numbers here for example, let us say 1, 2, 3 and so, on.

Now, the next is my vertices information so; that means, there are 3 vertices for each triangle. So, let us call this vertices as A, B, C, D, E, F, G, H. So, we have numbered all the vertices by A, B, C, D. So, now, for triangle number one I can see here that A, B and C they are the 3 vertices ok; and what about the neighbouring triangle? Ok, so, neighbouring triangles 2 triangle number 1 are 6 and 2 fine. So, let us consider the triangle number 2 now ok. So, for triangle number 2 we have vertices like A, H and C and what are the neighbouring triangles? Neighbouring triangles are 1 and 3 right.

Similarly, if I consider the triangle number 5 you can fill it for 3 and 4 also yourself fine let us consider the triangle number 5. So, what are the vertices here? We see here C, F and D and what are the neighbouring triangle? There are 3 neighbouring triangle 4, 6, 7. So, now, we can understand that this is the triangular irregular network data structure, this is the data structure of the TIN. That means how this data are stored in a memory or computer? So, I want to extract the information of let us say certain triangle for example, triangle number 4 or triangle number 5. So, I know that triangle number 5 consists of 3 vertices fine and triangle number 5 has 3 neighbouring triangles these triangles ok.

And we already know that these vertices have some coordinate for example, let us say that A, B, C and so, on. So, my A point has x A, y A, z A similarly, x by will have x B, y B, z B and so, on. So, using this information I can find out any information that is to be interpolated from this data set or from this data structure right. Now, I can see here that each this triangle is having some z value.

So, it is representing some kind of terrain, you can see here that TIN method is representing the terrain more faithfully. Because, they are considering the real points and they are developing the terrain surface. Now, what about the 3 D tetrahydron or 3 D triangulation? In this case I will have triangles which is in 3 D in nature; that means, that 3 points, 1 point, 2 point and 3 point. So, I am developing a triangle like this and similarly, I will connect this triangles and I will represent the complete surface as it is on the surface of earth.

And so, I want to find out the z value within the triangle, what will I do? I will take the x and y value and I will put this x and y value and then I will try to interpolate using the 3 vertices of the 3 D triangle. And I will find out the what is the value of the z value which is lying on the plane of a certain triangle.

So, there are 2 ways of this thing doing it the vector based algorithms. Now, I am representing the terrain by 2 ways one is my raster based that is digital elevation model or I can also represent it by the vector based algorithm in the form of triangular irregular network or TIN. Question is how can I extract the buildings as well as digital terrain model? So, first consider the digital terrain model ok.

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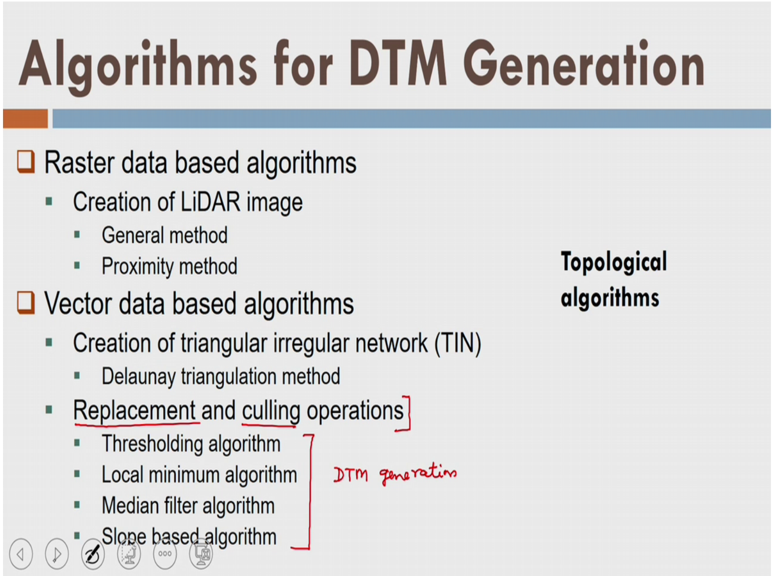

In order to develop the digital terrain model from LiDAR data we have vector based algorithm raster based algorithm also as well as we have some 2 or more operation, one is called the replacement and one is called the culling operation. They are in addition to my digital elevation model or to my vector model that is TIN model.

So, they are going to implement this replacement and culling operation also after developing my DEM or may be tin. So, that I can find out the terrain or I can extract the terrain information ok. So, there are 4 methods we generally employ for DTM generation right.

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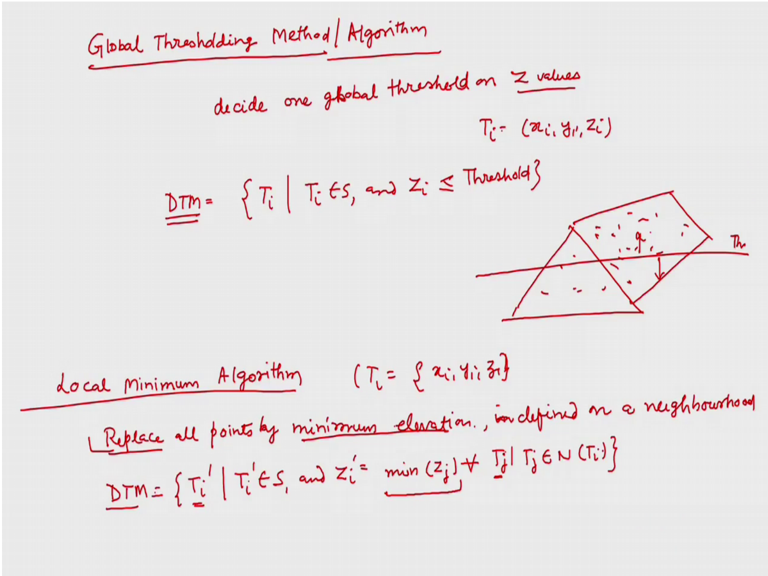

So, first method is my global thresholding method or I can see here the thresholding method algorithm and call it method whatever right. So, in this method what do we do? We decide one global threshold on z values right. The purpose here is above this global threshold whatever points are falling I will remove those point form a digital elevation model or may be TIN model whatever right. So, what will happen that global threshold value if I consider it very appropriately it will in one attempt it will remove the all points which are let us say belonging to tree or building also then we will have the real terrain that was originally there when there was no tree and there was no buildings were constructed.

So, now I have the global thresholding method if there is a point T i as given by x i, y i, z i and I can create the DTM as by point T i; that means, point T i will belong to the DTM. Given T i is in the space and Z i is less than or equal to certain threshold. The problem here is the moment we decide the global threshold it has to come from some logic and this logic is generally not true because, for tree or building or any structure I cannot have a global threshold. This sloppy roof of a building right like this it is very common in Guwahati.

So, whenever we feel that there is no fall or may be the rainfall are in access such structures are very common. Now, if I have some data and if I define some kind of threshold global threshold like this, what will happen? This data will be removed which is above the this global threshold and this data will be part of the DTM which is not true. So, that is a problem is in the global thresholding algorithm.

And now, what we do we can define our new method called local minimum algorithm, which is an improvement over the global thresholding algorithm. I can right here algorithm. Let us assume that again point T i is given to me which is nothing, but x y, y i, z i ok. Now, according to local minimum algorithm we replace all the points by minimum elevation ok. So, how to find out this minimum elevation? So, first define the neighbourhood.

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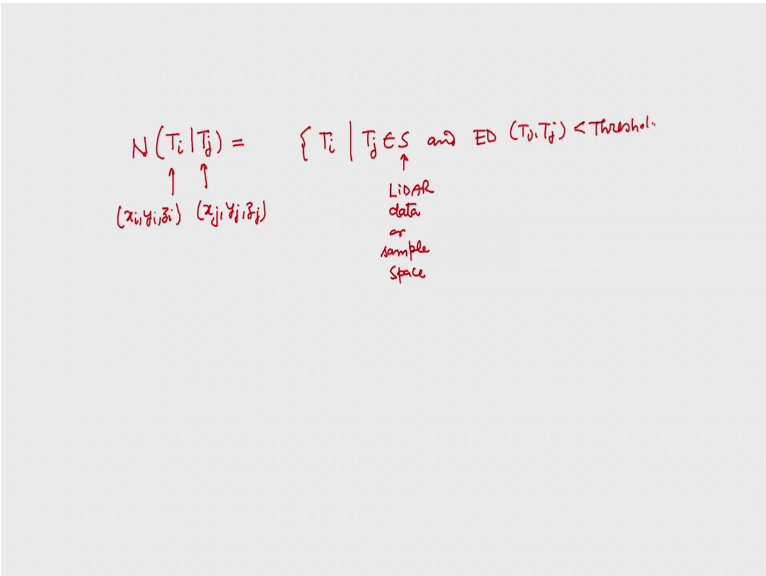

So, let us see that the neighbourhood is my point T i given my location T j ok. So, all these 2 are points are my LiDAR tuple. So, I am saying that the point T i is my neighbourhood at a given location T j or for the given point T j right ok. So, how to define this thing? So, let us say the point T i given the T j point is in the sample space or my LiDAR data or I can say is as the complete sample space and the Euclidian distance between the T i and T j is less than some threshold.

So, this is the way we define it. So, this minimum elevation is defined on a neighbourhood and we already learned that how to define a neighbourhood. So, let us see my DTM is equal to T i dash I am writing, since I am replacing the points. So, I am writing now T i dash not the T i, given the T i dash is in the space and z a dash is equal to the minimum of my z j where all the T j are in the neighbourhood of i point.

So, this is the way we write our algorithm for DTM. So, this is the way we replace our elevation of point by T i dash given that the z i dash is equal to the minimum of all the z j, where z j belongs to T j and T j is the neighbourhood of the T i; that means, using the neighbourhood information I am finding out around a point T i and I am replacing the z values of T i using the some neighbourhood information. So, that is my local minimum algorithm right.

So, now I can see that I am doing some operation not by global method rather I am doing by the some local kind of logic. I am defining a neighbourhood in a local point around the point in a local way and then using that particular data set only I am replacing the candidate pixel or candidate point by the local minimum and trying to find out the this one ok. So, what about the problems here?

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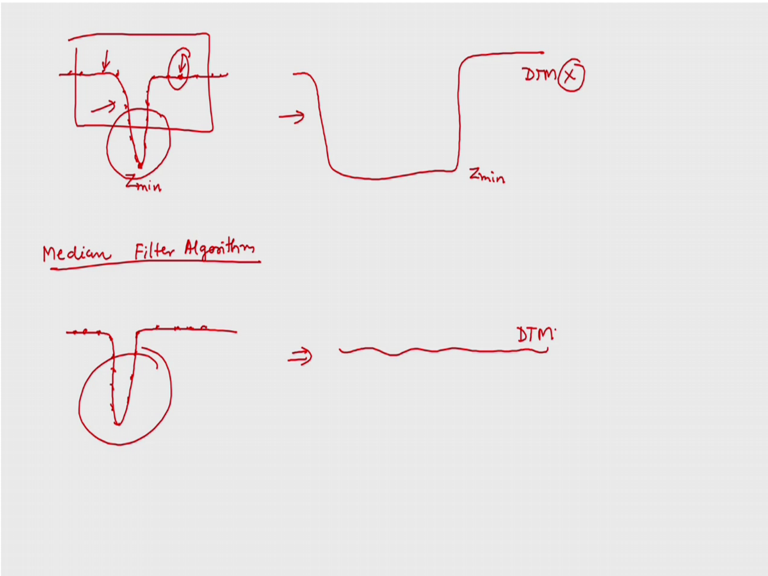

Let us say that the situation where my terrain is like this there is a small valley because my LiDAR points are here. And I have defined and this valley is not part of DTM rather it is kind of small pit. What will happen here? This is my z minimum of all the neighbourhood if I define the neighbourhood like this. So, this becomes the minimum one right what will happen now I will get my DTM like this where this is my z minimum and. So, it becomes this structure becomes wider like this and that is a problem this is my not 2 DTM ok.

So, in order to avoid such situation we need to improvise our algorithm. So, we have new algorithm called median filter algorithm. What is the median filter? Ok. We have the median term from the statistics. So, what we will do we will find out the median of all this point and that point will be somewhere here because we know that this data is very less in numbers. So, if I take the median by arranging in descending order ascending order I find out some point may be here or may be here.

Ok, now if I replace this all the points by this median what will happen? For this kind of terrain where these are my points; my DTM will be like this; that means, I have avoided this complete part which I know that is not a very true ok. So, this is my DTM what is a problem with this median filter also? Ok, let us consider a situation.

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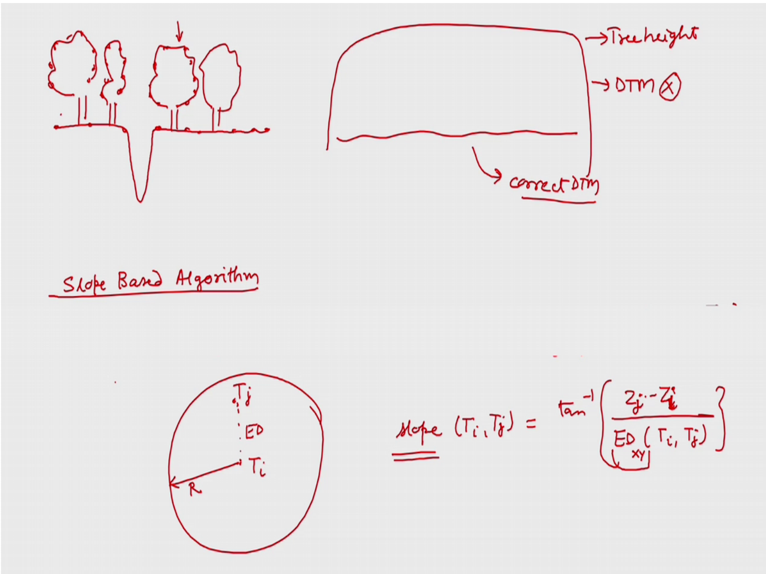

Let us say there is a small here which here valley here and then we have lot of trees here and trees are surrounding this small area and I have data over there, there, there all this thing. Here also I have terrain data, here, here, here also. So, all this what will happen now if I take the median of such data set I will get some median at the top of the tree. Now, what will happen? Instead of getting this terrain I will get the this kind of terrain where this is my tree height. So, this is not my DTM, this is wrong DTM fine. So, this is a correct DTM ok.

So, these kind of problems are there in the median filter algorithm. Even we take more we will face the same problem ok. Now, in order to avoid all this situations what we do?

We develop some more algorithm like slope based algorithm. What is slope based algorithm? Ok, let us say that if there is a neighbourhood like that and I have a point T i here and there is a let us say Euclidian distance here with another point called T j right.

So, this is my range r or my neighbourhood right ok. So, now, if calculate the slope between T i and T j that will be what tan inverse of Z i minus Z j divided by Euclidian distance between the T i T j and we are finding out equivalent distance on x, y only. So, this is my slope here between the 2 points, 2, 3 D points here right and remember this distance is Euclidian distance on the 2 D plane x, y only right. So, basically I am determining the slope more over if I consider slope like this condition. So, all this slopes are negative or I can say here let us put this thing that Z j minus Z i does not matter. So, if I consider the positive slope fine like this. So, now, this is the algorithm which are called slope based algorithms ok

So, now you can see that we have written these algorithms for DTM extraction using the vector data. I can also write those things in the raster also. These are the methods which are generally used for the digital terrain model development. What about the third aspect? That is the building information extraction. So, let us look into those also now ok.

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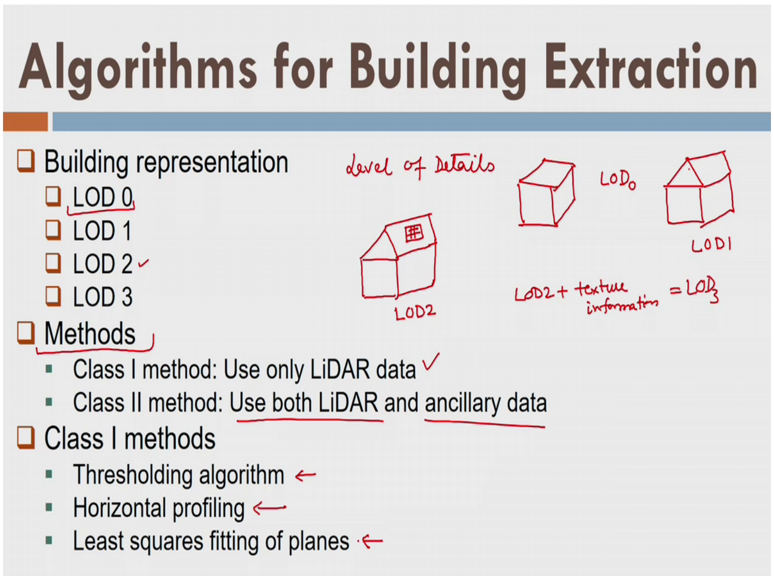

Then we have some building representation that we should first understand. So, there this is called the LOD 0 which is my level of detail. So, I can say that what is a LOD 0? Load is 0 is nothing, but the building with the simple model. Suppose, if I have the building like this the 3 D building and I am representing by the edges. So, this is the LOD 0 ok, what is LOD 1? That level of detail 1, if I have the sloppy roof and I am representing them in my model building model then it is called the LOD 1 ok.

What about the LOD 2? If I have some architectural details for example, this is my LOD 2 on top of that if I has some architectural details also like this there is window here and I am having this window also represented in my model building model then it is called LOD 2. And the LOD 3 is nothing, but if I have the LOD 2 plus texture information or the colour information of the building surface I call it LOD 3.

So, according to the level of detail I need to decide that which algorithm I should use or which algorithm I should develop. So, the ultimate purpose is I want to ultimately present my building in either this form. So, then I can characterize that what is the quality of my or what are the level of details available to my buildings using the LiDAR data that I extracted. So, now, the building extraction methods are in 2 classes, the class one methods are uses only LiDAR data and class 2 method use both LiDAR and the ancillary data.

Ancillary data means any additional data for example, texture information or the image data or with thermal image data or whatever. Any additional information other than the LiDAR data is call ancillary data. So, if I used ancillary data along with the LiDAR data the method will be categorised in the class 2 methods right. Class 2 methods are more efficient in terms of extracting the building because we have some additional information also. So, here we limiting ourselves to class one algorithms only ok.

In the class 1 algorithm now we are going to consider the 3 algorithms thresholding algorithms, horizontal profiling and the least squares fitting of the planes ok. So, let us consider each one by one.

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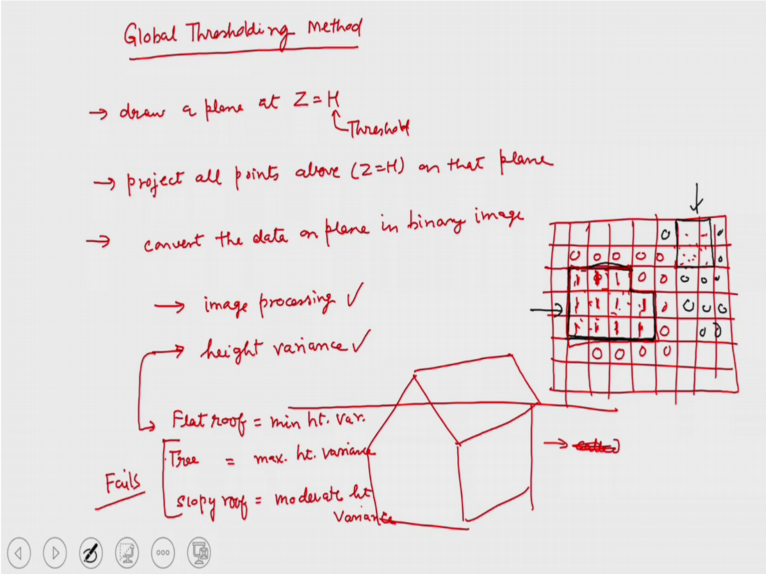

So, again my global threshold method or thresholding algorithm in this I define a global threshold in order to detect the buildings from the complete data ok. I know that there are some characters buildings have roof tops which are having certain height. If I define a global threshold what will happen? The points which are lying above the that plane or above this threshold will be called the building and all the rest of the data will be rejected; that means, all the data for example, it could be any data let us say terrain or it could be tree or whatever.

So, that will be rejected they will not be classified into the building. First idea here is in cases of the draw a plane at Z is equal to H this is my threshold ok. Then next is we project all the points above Z is equal to H on that plane. Which plane? Ok, then we convert the data on plane in binary image. What is binary image? We have binary image 0 and 1; that means, if I have plane like this and data is falling like this which are belonging to building right something like this. There is another building like this all this data point are there.

Now, I will say that divide this into the grids complete plane and if there is a point LiDAR point in a certain grid I will call that grid as one or 0. So, this is my 1, this is 0, this is my 1, this is 0, this is 0, 0, 0, 0, 0 and so, on. This is my 0 sorry this is 1, this is yeah and now I can say here there is a 1 right. So, all this 1 here, 1 here, 1 here, 1 here, 1 here, 1 here now I can say that fill pixel belongs to the building. So, I have this is my building here you see let us say the line here right. So, I got this building fine. So, a building shape so, this is a way I extracted my building fine. Similarly, I can extract here this building easily you can see here all the rest of the values are 0 here and all these values are 0 now.

So, this is the way I have extracted my 2 buildings here right this and this. So, that is what my global thresholding method, the first thing is that we can use some kind of image processing the way I shown you on the binary image right. And there we can consider the height variance also. What is height variance? If I consider the height of the building and since the buildings are flat what will happen?

Flat buildings having the same heights will have minimum variance of the height and as a result I can say for this particular area which is my building I will have minimum height variance. So, I will collect those height variance value for each pixel and then I will say that ok. Now, assume wherever height variance is minimum is my building top.

So, now, I can this way I can use either this method or this method in order to extract the building shapes. Fine, there is a problem because since we have global thresholding here right and that is also define manually by judgement. There could be possibility I can lose the data of sloppy roof like this.

So, my if the global threshold is like this I will lose the sloppy roof here and that is not desired. In such cases what to do? Ok, I would like to tell you one thing here when we calculate the height variance here you should know that for the flat roofs we have minimum variance. For the trees we have maximum height variance ok.

Then what about the sloppy roof? We have some moderate; that means, in between the maximum and the minimum value. So, we should understand this information. So, so we have seen the problems in such cases it fails ok.

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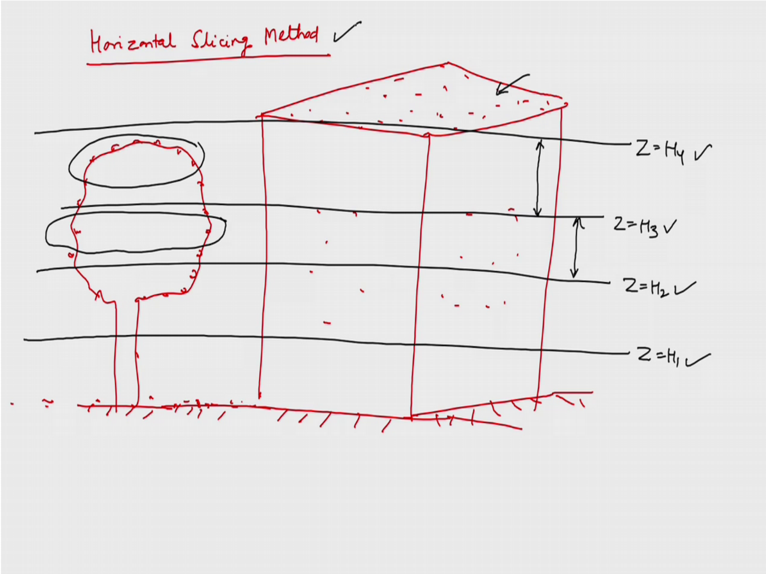

Now, so, we device another method called horizontal slicing method ok, what is the horizontal slicing? So, let us see I have some data for example, there is a tree like this and there is a building let us see this is my building here. Fine, now I can understand easily. And I have data all along here all the surface of build. This tree here, here I have data here everywhere fine. Similarly, here and I have data on the top of the building right or may be some data on the sides also available to me, but chances less on the sides more in the data on top and so on.

Now, you can see here that if I do the slicing the horizontal slicing of this data like this I am creating the slices of the data, they are planes. So, let us call Z is equal to H 1, Z is equal to H 2, Z is equal to H 3 and so, on Z is equal to H 4. Fine, now I consider between these 2 thresholds or between these 2 slices whatever data is there right and I can see here for a tree we have this data and for a building we do not have any data fine. Now what about this band?

This band is also having some data for that tree, but we do not have any data for the building because all building datas are here. Now, I will find out the building shapes for the each plane or the shape of the structure for each plane, for this plane also, this plane also, this plane, this plane also using the same method what we have done just before right, each plane will have certain shape of the trees as well as buildings. Now, if I consider all 4 bands or 5 bands or n number of bands in one way and I try to find out the CGs of the points or of the structure may be tree and building so, on.

What will happen in each band I will find out the same CG for the building because building CGs does not vary much, but in case of tree since trees have very very shape different varying shapes, what will happen ? Then CG will keep on shifting from different planes looking at the changes in the CG locations I can say that this is my tree structure. So, remove it from the data and that is my building structure accepted. So, that is what we call the horizontal slicing method here. I hope that you can appreciate these methods now ok. The third one is the planar surface method.

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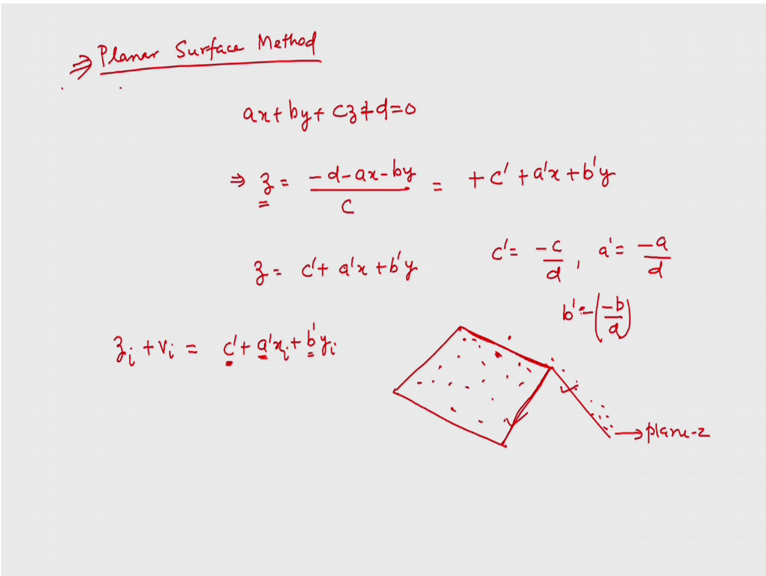

What is planar surface method? Planar surface method says that for a given data you try to fit the planes. And what is the definition of plane? The mathematically we write b or may be plus b is equal to 0.

So, now you can see that z is equal to minus b minus a x minus b y upon c or I can right here minus let us say c dash minus a dash x or we can say here plus b dash y. So, I can write z is equal to c dash plus a dash x plus b dash y where my c dash is equal to minus c upon d a dash is equal to minus a upon d and b dash is equal to minus b upon d here right.

Now, what will I do? I will use the method of least squares and there that is my observed value plus I will say that there is some error here and now I am fitting a plane c dash plus a dash x plus b dash y. So, the given points so, I have my x i, y i. So, let us say if there is a roof top like this and I have some data here and which has some errors and there is a another roof top here right.

So, now what will happen when I fit a plane through this points I will get what the values of a, c dash and b dash. Similarly, if I have some data over there and if I fit a plane that is my plane 2 I will have the fitted plane like this. This is my fitted plane and this is my fitted plane here. Now, if I intersect my to fitted place I can reconstruct a building and experimentally it is proven that using the least squares method we can also detect the edges, very efficiently we can detect these edges of the buildings which originally we cannot extract from the given LiDAR data.

Because, LiDAR data is may be here and it could be here also anywhere, but if a moment if I fit this lines or the planes I can extract these edges very nicely. So, this is the approach of the planar surface method. These are the very preliminary methods which I discussed with you today.

So, today we have learned some preliminary method that are used for LiDAR data processing in order to extract the information for various purposes. We have learned how to extract digital elevation model, digital terrain model information and we also learned how to extract the building information right. We finish this lecture here and we will meet in the next module, module 8 on radar.

Thank you very much.