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Generation of DSM for building model construction from Airborne LIDAR data

Aiswarya PT, Dr.J. Rajeesh

***Abstract*— Generation of Digital Surface model (DSM) is essential for the construction of building models from the airborne LIDAR data. LIDAR, known as Light Detection And Ranging, uses laser pulses for the detection of buildings. It emits laser pulses continuously to the earth surface and reflected light is analyzed. Laser first reflects from the top of the objects and as laser can penetrates, final reflection will be from the ground surface. Thus, by analyzing the first reflection, the objects on the earth surface can be identified. One of the most essential step in the identification of building model is the creation of Digital Surface Model. Digital Surface model is the model of earth surface consisting of all its features such as buildings, trees, vehicles etc. Thus, by analyzing the DSM, it is more easier to identify the buildings from all other features of the earth surface. Airborne LIDAR generates irregularly spaced 3D point measurements. So, before the processing of LIDAR data, irregularly spaced 3D data are converted to a regularly spaced 2D data for convenience.**

***Index Terms*— Laser pulse, Lidar, Point clouds**

I. INTRODUCTION

Creation of 3D building model from LIDAR data is essential in estimating urban population, property tax, building base elevation for flood insurance and also can be used for visualization in GIS. Lidar is a remote sensing technology that measure ranges to the Earth by transmitting Laser lights and analyzing the reflected light. Ultraviolet, visible or infrared lights can be used by LIDAR systems to visualize objects and can target a wide range of materials, including non metallic objects, rocks etc. The three dimensional set of points is created based on a scanning laser combined with both GPS and inertial technology. Thus, each point has a set of x, y and z coordinates to reflect its position and elevation. By analyzing the reflected signal strength, the ground reflections can be easily identified, since it has the strongest reflection and comparatively large time taken for this. Each pulse signal undergoes multiple echoes in which the first return is from the top of trees or vegetation. As laser penetrates the canopy the last return are received from the earth. The time difference of return signal from any object and that of the ground will give the height of that object as the speed of light is known. The time difference between the pulse emission and the detection of reflected signal gives the distance to the target. The radiation scattered from an object at a closer distance comes back sooner than that of from an object at longer distance. Scattering not only occurs on solid particles but also from the molecules and particles in air and water. The return signal will not be of the same length as the transmitted pulse, but extended in time, with a huge but short peak from a solid object. Airborne LIDAR can be used efficiently for the extraction of building models since they are not influenced by sun shadow and distance compared to aerial images and satellite images.

The Lidar point measurements can be divided into two: ground points and non-ground points. Ground points are the points related to bare earth surface and non-ground points are those points related to features of the earth surface such as buildings, trees, vehicles, vegetation etc. So, the critical step for the detection of building model is the separation of ground and non-ground points. Vosselman[2] introduced a slope based filtering for the separation of ground and non-ground points. It is based on the assumption that there will be no abrupt height change in the case of ground points. But this filter produce error when detecting the vegetation because, over dense vegetation it is difficult to obtain the height difference. By using different maximal slope thresholds, Sithole[3] modified the slope based filter. In this method for calculating the local slope threshold, a rough slope map is needed. The difficulty in this is to find an optimal neighbour of a point. So, to improve accuracy, DSM generation is introduced before separating the ground and non-ground points. DSM can be effectively derived using a high resolution satellite imagery[1]. It gives high accuracy, but it needs an extra data source other than Lidar. So, here, DSM model is generated only with the help of the Lidar point measurements with maximum accuracy.

II. ALGORITHM FOR DSM GENERATION

The Lidar data set is a 3D irregularly spaced point sets. Each point contains set of x, y and z coordinates reflecting the position and elevation details. Before separating ground and non-ground points, the data set must be converted into regularly spaced 2D array. The following is the algorithm for

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***Aiswarya PT**, M.Tech Scholar (Signal Processing), Department of Electronics and Communication, TKM Institute of Technology, MusaliarHills, Karuvelil P.O, Ezhukone, Kollam-691505, Kerala, India*

J.Rajeesh, Head Of the Department, Department of Electronics and Biomedical Engineering, TKM Institute of Technology, MusaliarHills, Karuvelil P.O, Ezhukone, Kollam-691505, Kerala, India;

the conversion of irregularly spaced 3D array to regularly spaced 2D array.

Algorithm:

Step 1: Collect the Lidar data in .las format.

Step 2: Create two matrices corresponding to both x and y with rounded off values in x and y.

$$Xs = round(x) \text{ and } Ys = round(y) \quad (1)$$

Step 3: Create another matrices of order 1 x n and 1 x m which contains the values starting from the minimum to maximum value.

$$Xi = min(Xs) : max(Xs) \text{ and } Yi = min(Ys) : max(Ys) \quad (2)$$

Step 4: Then, create a new matrix X of order m x n, such that, the rows of the new matrix are the copies of the above obtained matrix Xi. Similarly, for Yi, create a new matrix Y of order m x n, such that, the columns of the new matrix are the copies of the above obtained matrix Yi.

Step 5: Create DSM matrix by entering the values of z. The cell to which the values are entered is identified by the x and y values in the matrices Xi and Yi.

Lidar data collected in .las format are having x and y coordinates with large decimal values. So, in step 2, the values are rounded off to nearest integer. The rounding should be done according to a condition such that the maximum value in the matrix must be rounded off to minus infinity and
minimum value should be rounded off to plus infinity. Then, the minimum and maximum values of both rounded x and y matrix are taken. A new matrix of order 1 x n is created such that the minimum value is entered in the first cell and maximum value in the last cell. Intermediate cells are filled with the integers in ascending order from the minimum value to maximum value. This is done in step 3. In step 4, a new matrix of order m x n is created in such a way that the rows of the new created matrix are the copies of the matrix obtained in step 3. That is, the rows are repeating. Similarly, another matrix of order m x n is created such that, the columns of the new matrix are the copies of the matrix obtained in step 3. That is, in the second matrix the columns are repeating. Finally, DSM matrix is created by analyzing the two matrices obtained in step 4. The values of the z matrix are entered in the DSM matrix. The cell to which the values are entered is determined by the values of the matrices obtained in the previous step. That is, The values in the first cell of both matrices are taken. The corresponding z value is taken from the Lidar data and is entered in the first cell of the DSM matrix. Thus DSM matrix is obtained. But, when the Lidar is converted to regularly spaced array in the second step, some new values are added. The z values corresponding to those new values cannot be determined. Such cells are filled by neighbourhood interpolation method. Thus obtained DSM matrix is used for the separation of ground and non-ground points.

III. RESULTS AND DISCUSSIONS

The proposed algorithm is applied to three different areas and the corresponding Digital Surface Models are generated. The proposed method automatically generates the Digital Surface Models efficiently. The three Lidar data are downloaded from the 'Open Topography' website for Lidar.

The terrain features of the three areas are clearly obtained using the proposed method. From this DSM, the building models can be easily separated effectively. The effects of shadows are not affected for the generation of DSM. This is the main advantage of using LIDAR technology. The DSM generated will be independent of sun inclination or shadows. By considering the accuracy, speed and density of data, Lidar is found to be cheaper in many applications. This Digital Surface Models are not only used for the detection of buildings but also for the detection of water bodies, roads, forests etc.

Fig. 1. Digital map of the area where Lidar is collected and the generated DSM model

Fig. 2. Second example: Digital map of the area where Lidar is collected and the generated DSM model

In previous years, David C. Mason[7] proposes an algorithm called skewness balancing for the generation of DSM, which uses the statistical moments for the characterization of point clouds. It clearly separates the detached objects efficiently and can be effectively used in commercial applications. But, when comes to complex areas, it gives very less accuracy in the case of attached buildings. Also, further enhancement should be done in order to make it effective in very sloped areas.

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Fig. 3. Another example: Digital map of the area where Lidar is collected and the generated DSM model

In another method, F. Rottensteiner[8] proposes an interpolation method using skew error detection for the generation of DSM which purely depends on the skewness between terrain and non-terrain points. And hence, this method does not work in areas with less terrain points. Also, DSM is generated with the help of aerial images combined with Lidar data. But, this aerial images are sometimes affected by the shadows. But in the proposed method, there is no need of any external resources other than Lidar and also shadows are not affected.

IV. CONCLUSION

In this paper, the Digital Surface Model (DSM) of the earth is created efficiently and effectively. The DSM contains all the terrain features and can be used for the detection of building models or for the estimation of forest, water bodies etc. The DSM is generated with maximum accuracy only with the collected Lidar data. By the integration of additional source such as, High Resolution Satellite Imagery(HRSI) along with the Lidar data, the accuracy of the DSM generation can be increased.

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Aiswarya PT received her B.Tech degree in Electronics and Communication Engineering from Calicut University in 2013. She is currently pursuing second year M.Tech in Signal Processing at TKM Institute of Technology.

Dr. J. Rajeesh received his B.Tech degree from Madurai Kamaraj University in 1990 followed by M.Tech from the same University in 2002. He has published in national and international journals and guided many UG and PG projects. He worked with Dr.Jeyasekaran Medical Trust, Nagercoil from 1992 to 2000 as a Biomedical Engineer. During that period he developed automatic ECG machine and some critical components. His research areas are Biomedical Imaging, Biomedical Instrumentation, Embedded System, Digital Signal Processing and Digital Image Processing.