

Detection of Building in Airborne Laser Scanner Data and Aerial Images

Dilli Raj Bhandari
Survey officer
Survey Department
dillisurvey@gmail.com

Key words:

nDSM, planar segmentation, feature extraction, mean height of nDSM, NDVI, standard deviation of nDSM.

Abstract

The automatic extraction of the objects from airborne laser scanner data and aerial images has been a topic of research for decades. Airborne laser scanner data are very efficient source for the detection of the buildings. Half of the world population lives in urban/suburban areas, so detailed, accurate and up-to-date building information is of great importance to every resident, government agencies, and private companies.

The main objective of this paper is to extract the features for the detection of building using airborne laser scanner data and aerial images. To achieve this objective, a method of integration both LiDAR and aerial images has been explored: thus the advantages of both data sets are utilized to derive the buildings with high accuracy. Airborne laser scanner data contains accurate elevation information in high resolution which is very important feature to detect the elevated objects like buildings and the aerial image has spectral information and this spectral information is an appropriate feature to separate buildings from the trees. Planner region growing segmentation of LiDAR point cloud has been performed and normalized digital surface model (nDSM) is obtained by subtracting DTM from the DSM. Integration of the nDSM, aerial images and the segmented polygon features from the LiDAR point cloud has been carried out. The optimal features for the building detection have been extracted from the integration result. Mean height value of the nDSM, Normalized difference vegetation index (NDVI) and the standard deviation of the nDSM are the effective features. The accuracy assessment of the classification results obtained using the calculated attributes was done. Assessment result yielded an accuracy of almost 92 % explaining the features which are extracted by integrating the two data sets was large extent, effective for the automatic detection of the buildings.

Background

Airborne laser (Light Amplification by Stimulated Emission of Radiation) scanning (ALS) also known as LIDAR (Light Detection and Ranging), is an active remote sensing technique. A helicopter or an airplane mounted sensor sends laser pulses towards ground and records the elapsed time between beam launch and return signal registration. The accurate reflection point location can be calculated using time taken by a beam to return to the sensor, the beam shooting direction, the position and altitude of the sensor recorded with a Global Navigation Satellite System receiver (GNSS) and inertial measurement unit (IMU).

Airborne laser scanner data has proven to be a very suitable technique for the determination of the digital surface models and is more and more being used for mapping and GIS data acquisition purposes, including the detection and modeling of manmade objects or vegetation (Elberink & Mass, 2000). For map updating, city modeling, urban growth analysis and monitoring of informal settlements, there is need for accurate information regarding the buildings which is traditionally collected by an operator. For large volume of work, this process is very tedious and takes a long period of time and eventually increased the cost of the project. In most of the cases only small percentages of the changes have taken place but the operator has to inspect whole of the area carefully in order to locate the building that have changed. Automated approaches are of great importance in such applications, as they can reduce the amount of manual work, and consequently lead to a reduction of the time and cost of the process (Khoshelham et al., 2010). Airborne laser scanning technique plays a vital role in the acquisition of the 3-dimensional point clouds of high density and irregular spacing data in the field of surveying and mapping. The airborne laser scanning technique represents a recent technology based on fast acquisition of dense 3D data and allowing the automation of data processing. In the recent years its use has been increased day by day. One of the most prominent application areas of this technique is extraction and modeling to create 3D city models. By measuring point clouds defined in the three dimensional coordinates, this

technique provides automatically Digital Surface Models. But for 3D city modeling, the discrimination between terrain and elevated objects based on this surface model is still a challenging task, since fully automatic extractions are not operational (Tarsha-Kurdi et al., 2006) III symposium, photogrammetric computer vision, Bonn, Germany, 2006. Many researchers have shown the capacity of LiDAR data in detection and extraction of the buildings (Maas & Vosselman, 1999). The automatic building extraction in the urban area from data acquired by airborne laser sensors has been an important topic of research in photogrammetry for at least two decades. Earlier, the automatic building detection approaches mostly depend on a monocular aerial or satellite image. These approaches faced a lot of difficulties with occlusion complex buildings and presence of vegetation. These difficulties are due to the lack of information in a single image for the algorithms (Khoshelham et al., 2010). Mainly buildings detection methods are based on classification of the data to eliminate other objects rather than buildings.

Objective

This study is aimed in exploring the techniques for the extraction of the features required for the detection of the building using laser scanner data and aerial images.

The main objective of the project is:

To detect the building from the airborne laser scanner data and aerial images for various purposes

Moreover, the specific objectives are

- To determine the set of features which can uniquely describe the buildings in the airborne laser scanner data and aerial images
- To find the appropriate entity for the classification of the buildings
- To assess the ability of nearest neighbour classification and rule based classification approaches in detection of buildings.
- To test effect of different attributes of segment in the classification process.

Study area and data used

The study area is Vaihingen city, which is situated close to the Stuttgart, Baden-Württemberg, Germany; its geographical coordinates are 48° 56' 0" North, 8° 58' 0" East. The test area is situated in the centre of the city Vaihingen. It is characterized by the dense development consisting of historic buildings having some trees, high

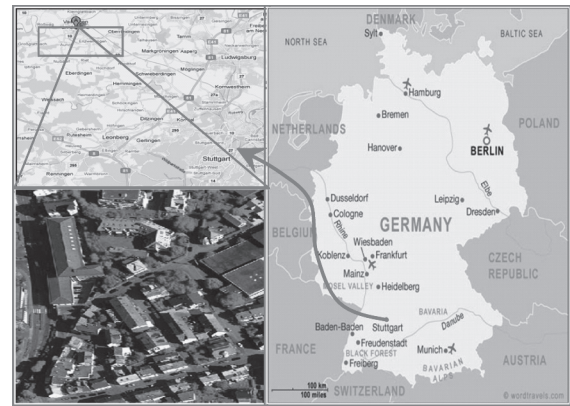


Figure: 1 Study area

rising residential buildings that are surrounded by trees and purely residential area with small detached house. The data used for the implementation of this study was captured over Vaihingen in Germany. This data set was captured and provided by the German Society for Photogrammetry, Remote Sensing and Geoinformation (DGPF) [Cramer, 2010]: <http://www.ifp.unistuttgart.de/dgpf/DKEP-Allg.html> (in German) for the test of digital aerial camera. These data set are for the test data from the ISPRS and used for the research purposes.



Figure: 2 Left: Laser scanner point clouds. Middle: digital aerial image. Right: Laser scanner DSM.

The digital aerial images are a part of the high-resolution DMC block of the DGPF test with 8 cm ground resolution. DSM was interpolated from the ALS point cloud with a grid width of 25 cm, using only the points corresponding to the last pulse.

Feature extraction procedure

The features extraction procedures give an overview of the set of the course of action, algorithms and the technique implemented to accomplish the required objective. This section of the study report endeavor bit by bit impending into the concrete process to meet the objective.

For the successful completion of any project it needs a clear plan and conception that will delineate the undertaking flow from one step to the next in order to complete the pre defined objective. A conceptual workflow diagram was outlined and used as strategy during the performance of the procedure.

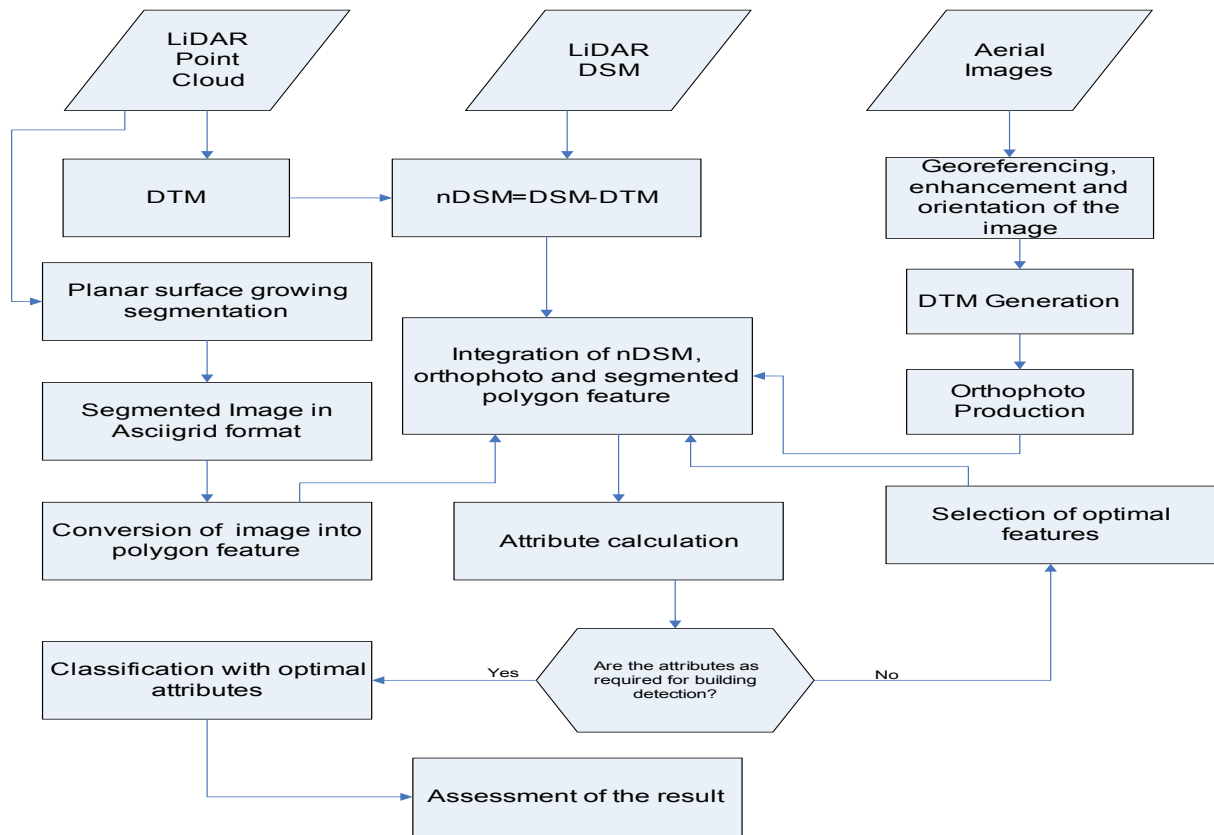


Figure: 3 Conceptual work flow diagrams.

Generation of the Normalised Digital Surface Model

Normalized digital Surface Model (nDSM) is a category of raster layer that correspond to a regular arrangement of locations and each cell has a value corresponding to its elevation. nDSM is the digital representation of the absolute elevation of the features above the surface of the earth. It is generated by subtracting the digital terrain model from the digital surface model i.e. $nDSM = DSM - DTM$. Hence it is the digital representation of the absolute height of the objects above the DTM. Here the Digital Terrain Model has been prepared from the LiDAR point cloud by using the smooth surface growing technique. A Digital Terrain Model is the elevation model of the landscape which does not have the object above the surface of the earth. Thus, the DTM correspond to only the bare earth surface. On the other hands Digital Surface Model takes account of topography as well as the features with their respective height above the surface of the earth. Thus the generated nDSM provides only the objects above the surface of the earth.

Information extraction from the aerial images and laser scanner data can be done from the smallest processing unit of the image with its features applied for the processing such as classification. The smallest processing unit can be determined as a pixel or an object in the image. In the past

and now a days, the single pixel based characteristics by the measurement of reflectance value from the surface of the earth have been used for the most of the methods in information extraction from the images. The traditional pixel based methods are not fully effective to extract information from the high resolution images because of the spectral complexity i.e. similar reflectance from more than one class and different spectral reflectance from one class without paying attention to spatial relationship among the neighbor. The object oriented analysis can overcome the limitation of the pixel based analysis. The initiative of object-oriented analysis is that images are broken down into spectrally homogenous segments or objects. Large number of parameters can be automatically calculated for these created segments like segment's spectral characteristics, texture, shape, orientation, proximity or adjacency to other objects etc. All or some of those characteristics can then is utilized to make rules that are in turn used to classify the segments.

Segmentation

Segmentation is an important step for the feature extraction from the available data by applying an appropriate segmentation algorithm and outlining parameters that could provide a most favorable segmentation pattern. A segmentation algorithm groups points that belong together according to some criterion. The most common segmentation of point clouds are those that group points

that fit to the same plane or smooth surface. Segmentation is then equivalent to the recognition of simple shapes in a point cloud (Vosselman et al., 2004). The appropriate segmentation algorithm for the detection of the building is planner segmentation as the geometry of the manmade objects can often be described by a set of planar surfaces. The most suitable algorithm for the detection of the building are surface growing which can be regarded as an extension to three dimension of the well-known region growing algorithm. For processing point clouds surface growing can be formulated as a method of grouping nearby points based on some homogeneity criterion, such as planarity or smoothness of the surface defined by the grouped points (Vosselman, et al., 2004). Surface growing consists of two steps: seed detection and growing. In the first step of the seed detection, a small set of the close at hand points is singled out that forms a planar surface. All points within a number of radiuses around a randomly preferred point are analyzed to determine whether some proportion of the point set fits to a plane. If this is not the case, another point is selected randomly and the neighborhood of this point is analyzed. One time a set of coplanar points has been established, this set represents the seed surface that will be extended in the growing phase. In the region growing step, all points of the seed surface are set onto a heap. Points on the heap are processed one by one. For each of these points, the neighboring points are determined using a data structure. If a neighboring point has not yet been allocated to a surface, it is tested to settle on if the point can be used to enlarge the surface. If the point is within the some distance of the plane fitted to the surface points, the surface label is allocated to the point and the point is situate onto the heap. In this fashion all points on the heap are processed and the surface is full-grown until no more neighboring points robust to the surface plane.

Normalized difference vegetation index:

The Normalized difference vegetation Index is a numerical indicator that uses the visible and near infrared bands of the electromagnetic spectrum and is adopted to analyze the laser scanner data and aerial images for the detection of the buildings. It has found a wide application in separation of the buildings from the vegetation. The vegetation has a significant spectral difference to buildings. Roofs of the buildings usually not covered by the vegetation; therefore we can find a features that represents vegetation in a stable way to separate the buildings. The bigger the difference therefore between the infrared and the red reflectance, the more vegetation has to be. The NDVI algorithms subtract the red reflectance values from the near-infrared and divide by the sum of the red and near-infrared bands.

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Where NIR = Near infrared band and RED = Red band

Mean height value of normalised digital surface model:

Building objects are always elevated. Thus Buildings are higher than a certain level. It can be used the height information from the nDSM for the recognition of the buildings. Difference of the height between the digital surface models and digital terrain model could be a good indicator to detect the buildings from the airborne laser scanner data and aerial images. The height of the objects depends upon the height of the point inside the segment. The elevation information is a very consistent source of information for the detection of the buildings. Most stable information for the detection of the buildings is their different elevation compared to their surroundings.

$$\text{Mean height value of nDSM} = \frac{\text{Sum of point heights}}{\text{Total number of points in segments}}$$

$$\text{Mean height value of nDSM} = \frac{\sum X}{n}$$

Where X is layer elevation value of the point. n is the number of the point forming a segment.

Standard deviation of the height of the normalised digital surface model

Standard deviation attribute gives the nature of the distribution of the height value deviated from the mean value. It is widely used measurement of the variability or diversity of the height of the objects. It gives an idea about how much the variation or dispersion of the height of an object from the mean value or the expected value. Standard deviation of the height is normally a very key attribute in building detection assessment as it is sharp indicator of the nature shape of the structure. To separate buildings and trees both are elevated object, standard deviation of nDSM has been an important feature to separate buildings from the trees as trees have very high elevation values close to very low elevation values due to the leaf off tree branches. Standard deviation of nDSM alone is not sufficient to separate building from the tree because some of the coniferous trees are not leaf off and give back a quite homogeneous elevation. It may be problematic for those building having gable roofs as they have height variation.

Standard deviation of the nDSM height

$$(\sigma) = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n}}$$

Where n is the number of the point forming a segment, x_i is the layer elevation values of all n points forming segment and \bar{x} is the layer mean value.

Relational boarder to building neighbor object

All objects have neighborhood relationships which could helpful for the extraction of the features. Thus, the attributes relational boarder to building neighbor object is based on the contextual information or the surrounding neighbor objects information on the classes of neighboring segments. This attribute is useful to separate the small segment which inside of the other segments. It is independent of the area of the segment so it is not useful to separate the bigger segments.

The area of segment features

Area of the segments is one of the important features for the extraction of the building. This attributes measures the area of the segments. It is calculated by multiplying the number of pixels formed the segment by the size of the pixel as $\text{Area} = [\text{Number of pixels}] * (0.25 * 0.25)$

Results

Figure 4 underneath exhibit the graphical depiction of the NDVI values by means of histogram. Here the value of the NDVI ranges from -0.2 to absolute value of unity.

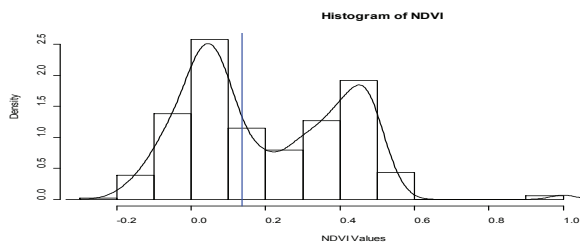


Figure: 4 Histogram of NDVI

The vertical line screening in the graph correspond to the threshold value something like 0.14, the value below of that threshold value represents the buildings segment and beyond of the threshold value represents the other objects like vegetation. Thus the buildings represent the portion in the graph having NDVI value less than 0.14. It is also clear from figure 4 that most of the buildings have NDVI value ranges from 0 to 0.1 having a peak density. Two peaks can be seen in the graph meaning two objects have more concentrated NDVI values. However, we can also perceive from figure that either the perfect vegetation has NDVI value of unity or the outlier values in the NDVI and some water bodies having negative values of NDVI.

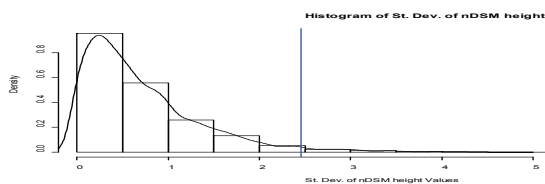


Figure: 5 Histogram of standard deviation of nDSM height

Figure 5 above demonstrates the graphical representation of the standard deviation of nDSM height value. The vertical line in the graph represents the threshold value something like 2.5, the portion in the graph below of that value represents the buildings and the portion in the graph beyond of that value represents the other objects like trees. Figure shows that small numbers of objects have high variation of the height. Most of the objects concentrated towards the lower value of the standard deviation showing the lower variation of the height. From the figure it is clear that the buildings have lower value of the standard deviation indicating the small variation or fluctuation in the height value and the trees exhibit the higher value of the standard deviation indicating the higher variation or fluctuation in the height values. From the figure, it can also be seen that the data exhibit the positive skewed as the left most side has the peaks of the histogram. The positive skew means that more objects obtained are in the lower values of standard deviation.

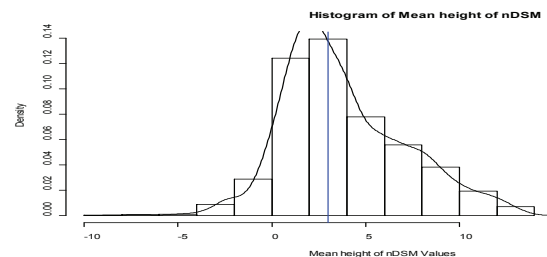


Figure: 6 Histogram of mean height of nDSM

Figure 6 above demonstrates the presentation of the mean value of nDSM height values using histogram. The vertical line in the graph represents the threshold value 3m which was set as the less than 3m object cannot suppose to be a building, below of that value represents the other object having low elevation and beyond of that value represents the elevated objects like buildings and the other objects trees.

Classification Result based on the nearest neighbour method:

Figure7 mentioned below represents the classification result obtained by means of the nearest neighbor classification technique using the three attributes normalized difference vegetation index, mean height of the nDSM and the standard deviation of the height of the nDSM. The relative legend shows the classification represents.



Figure: 7 Classification result based on the nearest neighbour classification method

Classification results based on the rule based classification method:

Figure 8 mentioned below represents the classification result obtained by means of the rule based classification technique using the three attributes normalized difference vegetation index, mean height of the nDSM and the standard deviation of the height of the nDSM. The relative legend shows the classification represents:

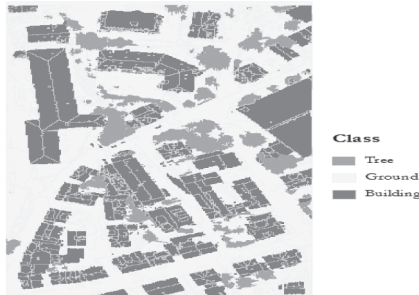


Figure: 8 Classification result based on the rule based classification method

Accuracy assessment of the classification result:

For the assessment of the results obtained from the Nearest Neighbor (NN) classification, the technique employed to evaluate the result is divided into four phases according to the attributes used for the classification in nearest neighbor classification method. In the NN phase 1, the attributes used were mean height value of the nDSM, standard deviation of nDSM height and NDVI. NN phase 2 refers to the attributes used were mean height value of the nDSM and standard deviation of height of nDSM. Similarly in the phase 3 the attributes used were mean height value of the nDSM and NDVI and finally in the phase 4 the attributes used were standard deviation of height of nDSM and NDVI. In the rule based classification (RB) all the attributes were used for the classification and the RB phase refers to the rule based classification. The assessment result obtained is presented in the following table 1.

Phases	Metric (%)		
	DR	R	OA
NN Phase 1	77.3	92.9	92.3
NN Phase 2	61.7	86.0	87.0
NN Phase 3	75.4	95.2	92.6
NN Phase 4	93.3	67.6	88.6
RB Phase	86.0	84.1	91.8

Table: 1 Assessment results

From the analysis of the results presented in the table 1, it can be seen that the overall accuracy (classification of building area as buildings and the other object as not buildings), the

user's accuracy (classified building is actually a building according to the reference data) as well as the producer's accuracy (building area classified as building) for NN Phase 1, Phase 3 and RB phase are greater as comparison to the other phases in which the attributes either used all three or only mean height of nDSM and NDVI. If standard deviation is used with other two attributes separately the accuracy slightly lowers. The overall accuracy of the two technique of classification namely nearest neighbor and rule based using three attributes is almost same 92 %.

Conclusion and Recommendations

Automatic move towards to building detection in airborne laser scanner data and the aerial images are extremely important in many applications like 3D city modeling, urban growth analysis, monitoring of informal settlements and map updating processes as it could diminish the amount of the labor-intensive work and consequently lead to a lessening of the time and the cost of the course. In general, in order to overcome the boundaries of image-based and Lidar-based system, it is of benefit to use a combination of these techniques. Investigating the best possible features for the detection of the building using airborne laser scanner data and the aerial images is the main goal of this paper. Thus, an integration technique of the LiDAR data and the aerial images to extract the features for the automatic detection of the buildings has been explored. Height information from the LiDAR is most important feature to detect the elevated object and the spectral information from the aerial images is an added important feature to separate buildings from the vegetation. Features namely mean height value of the nDSM; NDVI and the standard deviation of the height of the nDSM were extracted from the integration results of both the data set. Classification results obtained using these features are quite impressive. From the accuracy assessment result, it has been found that the overall accuracy of the detection of the buildings using the extracted features is 92 %. Thus, ninety two percentages of the buildings were automatically detected using extracted features. From the classification analysis result and the accuracy assessment of the result it is possible to conclude that the features which are extracted have been successful for the automatic detection of the buildings. Features extraction done in this study is based on the nDSM generated from the DSM which was interpolated from the ALS point cloud with a grid width of 25 cm using only the points corresponding to the last pulse. Other study and experiment can be done using multiple echoes and intensity for further research. Other studies and experiment need to be done for study area having complex scene and undulating terrain. It is recommended to move forward to explore the other features than the features extracted in this study to detect building using both the data set. In this study feature extraction for the buildings detection is premeditated using laser scanner data and the aerial images. It is recommended to move forward to

detect other objects like roads, trees etc. When buildings are covered by trees, either they cannot be detected or they can only be detected partially. In addition, multi-return LiDAR data can be applied to effectively differentiate trees from buildings in those cases.

References

Dhahal, R.K., & Bhandari, D.R. (2010). *Research Methodology and Statistical Methods in rural development*.

Elberink, S. O., & Mass, H.G. (2000). *The use of anisotropic height texture measures for the segmentation of airborne laser scanner data. IAPRS, XXXIII.*

J.A.Beraldin, F.blais, & U.Lohr. (2010). *Laser scanning technology. 3-42.*

Jahne, B. (2002). *Digital image processing.*

Khoshelham, K., Nardinocchi, C., Frontoni, E., Mancini, A., & Zingaretti, P. (2010). *Performance evaluation of automated approaches to building detection in multi-source aerial data. ISPRS Journal of Photogrammetry and Remote Sensing, 65(1), 123-133. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0924271609001191>. doi:10.1016/j.isprsjprs.2009.09.005*

Liu, X. (2008). *Airborne LiDAR for DEM generation: some critical issues. Progress in physical Geography. 31-49.*

Maas, H.-G., & Vosselman, G. (1999). *Two algorithms for extracting building models from raw laser altimetry data. ISPRS Journal of Photogrammetry and Remote Sensing, 54(2-3), 153-163.*

Rottensteiner, F. (2001). *Semi automatic Extraction of buildings based on hybrid adjustment using 3D surface model and managment of building data in TIS. PhD Thesis Viena, University of Technology.*

Schiewe.J. (2002). *Segmentation of high resolution remotely Sensed data Concepts, Applicationand problems. Symposium on Geospatial Theory, Processing and application(commission IV WG IV/7).*

Tarsha-Kurdi, F., Landes, T., Grussenmeyer, P., & Smigiel, E. (2006). *New Approach For Automatic Detection of Building in Airborne Laser Scanner Data Using First Echo Only. Paper presented at the ISPRS, III symposium,photogrammetrc computer vision ,Bonn.*

Vosselman, G., Gorte, B. G. H., Sithole, G., & Rabbani, T. (2004). *Recognising structure in laser scanner point clouds. International archives of Photogrammetry,remote sensing and spatial informationsciences,46(part8/W2), 33-38.*



Author's Information

Name	:	Dilli Raj Bhandari
Academic Qualification	:	Master of Science Degree in Geoinformatics, Sikkim Manipal University
Organization	:	Survey Department
Current Designation	:	Survey Officer
JOB/Work Experience	:	6 years
Published Papers /Articles	:	2 Papers in National Magzines
Email	:	bhandari25924@alumni.itc.nl