Lidar-ALTM and Its Application for Urban Planning and Infrastructure by Developing 3D City Model

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Abstract

In this developing era of modern trend of urbanization and industrialization there is an emergent need for proper city planning systems. 3D models are digital representations of the Earth's surface and related objects belonging to urban areas on the earth surface. 3D models are real world representation useful in applications such as 3D visualization, planning the city in Infrastructure development, Information system for tourism, Intelligent transportation systems, Environmental aspects, Disaster Management, public rescue operations, real estate market, utility management, Military operations, Training of officers, Simulation of new buildings, Updating and keeping cadastral data, monitoring change detection and virtual reality.

LiDAR data (Light Detection and Ranging) is a recent new technology for obtaining the earth's surface objects mainly for 3D building visualization. ALTM (Airborne Laser Terrain Mapping) data when combined with digital orthophotos can be used to create highly detailed Digital Surface Models (DSMs) and DEM from which Digital 3D City Models are obtained.

Various techniques and conditions were used to extract the objects and accuracy level is examined. Research in 3D GIS helps to analyse the replica of real world and the related issues. Here, in this paper the 3D objects are developed using ArcGIS and also by using algorithm techniques.

Keywords - *3D model, City model, Visualization, Infrastructure, Disaster Management*

I. INTRODUCTION

A. Lidar Technology

LIDAR (Light Detection And Ranging) is an optical remote sensing technology that measures properties of scattered light to find range of a distant target in the form of laser pulses. Its application is widely in archaeology, geography, geology, geomorphology, seismology, forestry, Urbanization, Town planning, remote sensing, Geomatics and Atmospheric physics.

ALTM (Airborne laser Terrain Mapping) is a recent new technology for capturing data of the topography of the earth surface features. It became feasible through the availability of lasers with Inertial Measurement Unit (IMU) and the Global Positioning System (GPS).

A typical LiDAR system is operated from a aircraft, a helicopter or a spacecraft. The setup rapidly transmits pulses of laser which travel to the surface, where they are reflected back. The return pulse is converted from photons to electrical impulses and received by a high-speed data recorder. Using the formula for the speed of light, time intervals from transmission to collection are easily derived. Time intervals are then converted to distance based on positional information obtained from GPS receivers and the on-board Inertial Measurement Unit (IMU) which constantly records the attitude of the aircraft. The data can be gathered during the day or night, weather and even in small rains due to its active system. LiDAR systems collect positional (x, y) and elevation (z) data at pre-defined intervals and the resulting LiDAR data is of very dense point clouds. The accuracy of the LiDAR data is a function of the flying height, laser beam diameter, the quality of the GPS or IMU data, and post-processing methods. Accuracies of less than 1 m can be achieved using LiDAR technology.

B. Objects in 3D GIS

3D objects are x,y,z coordinate features representing on the earth surface. These are extracted by using algorithms and conditions.

C. Need for the study

Accurate and timely 3D spatial information about buildings in urban areas is needed as the basis to assist decision making in understanding, managing, and planning the continuously changing environment. Construction of new neighbourhoods, transportation networks, and drainage systems are a few situations in which information about buildings is essential to the planning process. However, useful quantitative spatial information cannot be obtained directly from existing data sources and must rely on extraction techniques. Conventional field survey methods are time-consuming and costly. Planning maps are used widely in various urban applications because of their high accuracy, although producing and updating them are time-consuming and hard to automate.

Recently available high-resolution remotely sensed data have provided the potential to achieve effective and efficient building information through automated extraction methods. Aerial photographs are a popular data source for building extraction owing to their high resolution. However, they often cover selected areas only and lack multiple times of coverage for the same area, making it difficult to update the building database once created. High-resolution commercial satellite image data have been used increasingly in building extraction, but the issues of shadowing and distortion can affect the resulting accuracy to a certain degree of extend. A new data source, Light Detection and Ranging (LiDAR) data, is used in this project work, which provides land-surface elevation information (height) by emitting a laser pulse and providing high vertical and horizontal resolutions of less than 1 m.

II. GENERAL METHODOLOGY

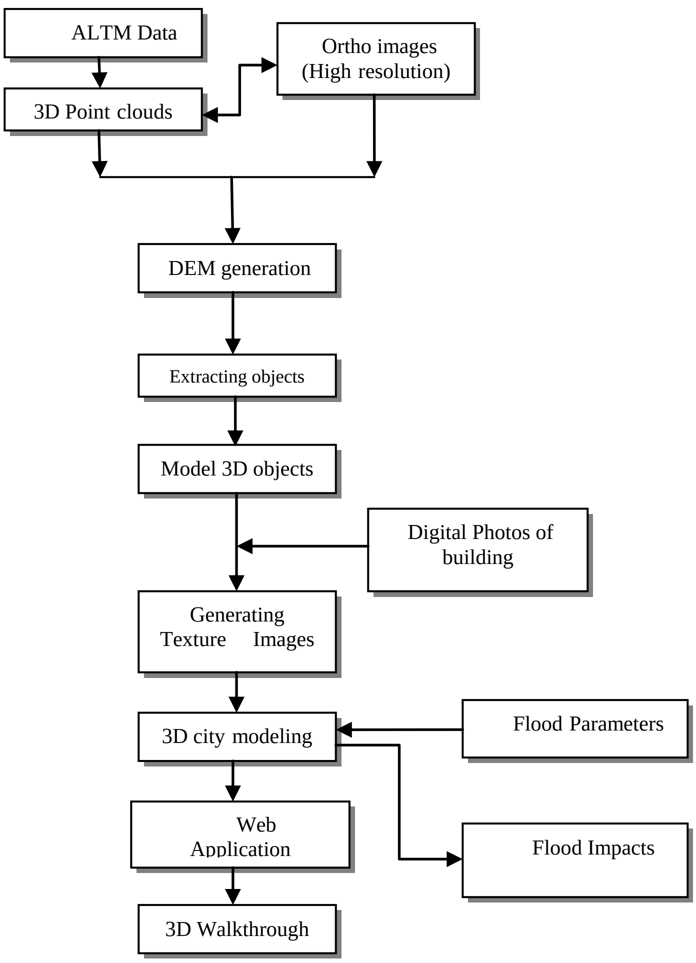

Figure 1. Flowchart for General Methodology

It is to define a proper rule to identify meaningful image objects owing to the fact that the object identification is influenced significantly by the knowledge and the quality of the data. Urban trees tend to be confused with buildings because of similar heights of trees and low-rise buildings.

Therefore, how to extract urban buildings accurately and efficiently from LiDAR data is one of the main aspect in current work. With this extraction of buildings, 3D model is generated to meet the need of solving the risks and issues in changing environment. The general methodology comprises steps required to develop 3D objects.

III. PREPARATION OF DSM METHODOLOGY

Digital Elevation Model (DEM) generated using Minimum Filtering Technique was used to eliminate the elevation influence from the digital surface model (DSM) derived from the LiDAR data so that a normalized height model could be computed.

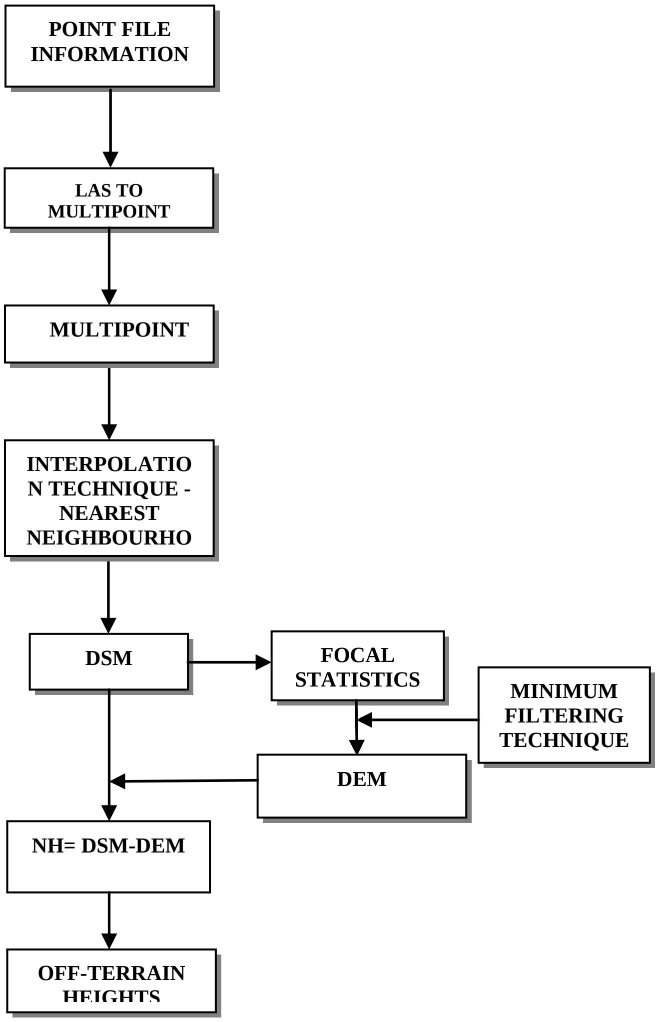

Figure 2. Flowchart for generating DSM and DEM

A. Point File Information

The LAS file format is a public file format for the interchange of LIDAR data between vendors and customers. This binary file format is an alternative to proprietary systems or a generic ASCII file interchange system used by many companies. The LAS file format maintains the information specific to the LIDAR nature of the data while not being overly complex.

B. LAS to Multipoint

This customized tool imports one or more files in LAS format, into a new multipoint feature class. Supported LAS file format versions are 1.0 and 1.1.

The .las point files are converted to Multipoints 3D using the syntax in script.

Syntax:

LASToMultipoint_3d <input; input> <in_feature_dataset> <out_feature_class> {average_point_spacing} {class_code; class_code...} {return;return...} {keyword {name}; keyword {name}...} {input_coordinate_system} {file_suffix}

C. Interpolation Technique

Interpolation is a method of constructing new data points within the range of a discrete set of known data points. Nearest neighbour resampling uses the digital value from the pixel in the original image which is nearest to the new pixel location in the corrected image. This is the simplest method and does not alter the original values. The Focal Statistics tool gives control over the neighbourhood type and statistics to be calculated.

x = (width of the neighbourhood + 1)/2

y = (height of the neighbourhood+1)/2

D. Digital Surface Model

Digital Surface Models (DSM) are widely used in the earth sciences. It provides information for various geological studies and other applications. There are a number of methods for automatic DSM generation, each of which has its own strengths and weaknesses, none of which are perfect. Even though there are plenty of algorithms to date which can generate the DSMs, it is a computationally complex calculation and does tend to take some time to complete. In order to achieve faster DSMs, an algorithm was implemented on a graphics processing unit.

E. Minimum Filtering Technique

A common filtering procedure involves moving a 'window' of a few pixels in dimension (e.g. 3x3, 5x5, etc.) over each pixel in the image, applying a mathematical calculation using the pixel values under that window, and replacing the central pixel with the new value. The window is moved along in both the row and column dimensions one pixel at a time and the calculation is repeated until the entire image has been filtered and a "new" image has been generated. By varying the calculation performed and the weightings of the individual pixels in the filter window, filters can be designed to enhance or suppress different types of features. Here, minimum filtering is used to find out the minimum value of kernel window in the neighbourhood to be considered as centre pixel for DEM extraction or Bare Earth Model.

F. Normalized Height Model

Normalized height model is derived from Digital surface model minus Digital Elevation Model.

$$NHM = DSM - DEM \quad (1)$$

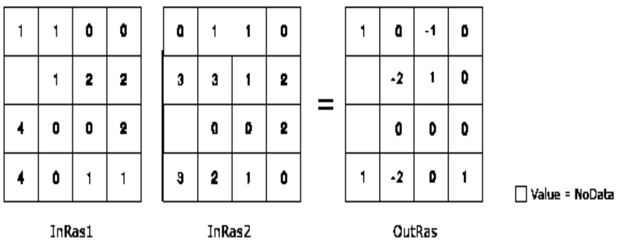

Figure 3. Concept of Developing NHM

IV. ACQUISITION OF 3D OBJECTS FROM ACQUIRED SENSOR DATA

Automatic building extraction from LIDAR Data is obtained by modelling without physically going to the exact location or object. From airborne LIDAR data, digital surface model (DSM) can be generated and then the objects higher from the ground are automatically detected from the DSM. The buildings, geometric characteristics such as size, height and shape information are then used to separate the buildings from other objects. The extracted building outlines are then simplified using an orthogonal or edge detection algorithm to obtain better effect.

A. Processing Of NHM or NDSM Data Methodology

These are the step by step approach to generate 3D models from NHM.

1) Building Extraction Technique

In this project, the function of feature extraction in the ArcGIS model builder was used to perform image segmentation. It includes a series of procedures for building extraction:

i. Segmentation: Image segmentation is the process of partitioning images into segments by grouping neighbouring pixels with similar characteristics.

ii. Merge: This process is used for solving the over segmentation problem and grouping small segments together.

iii. Threshold technique.

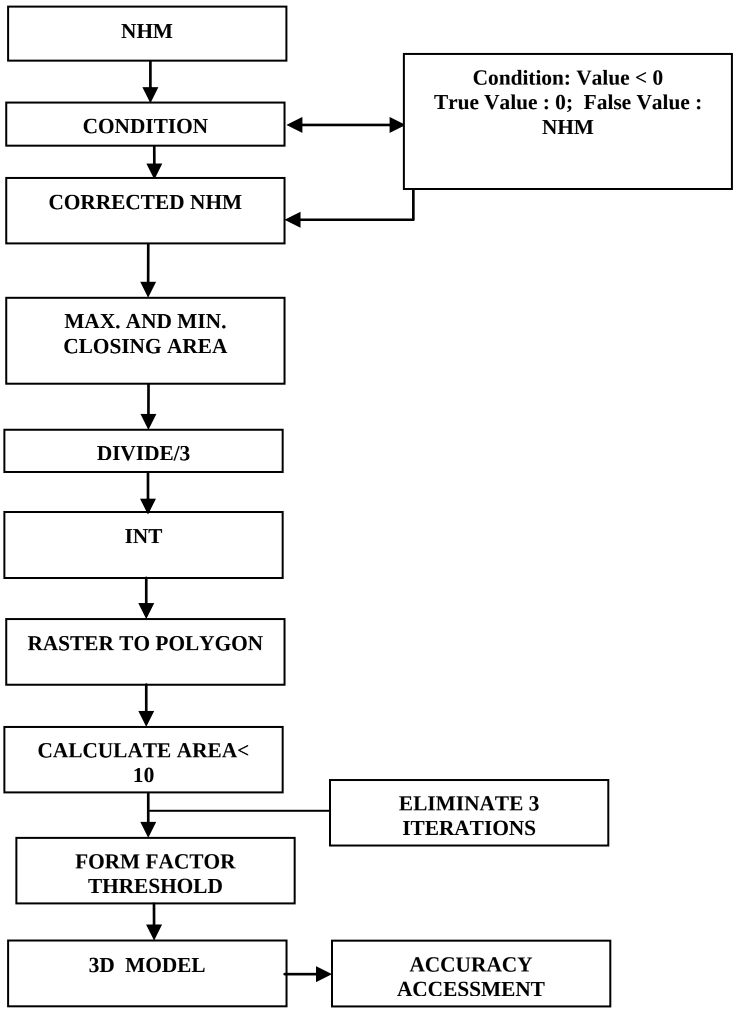

Figure 4. Flowchart for processing NHM

a) Corrected NHM: A correction process was needed to filter out abnormal points based on the following criteria:

Condition:

If IV of NHM < 0, then IV of NHM = 0;
Else IV of NHM = IV of NHM (2)

b) Divide 3D: Divides the values of two rasters on a cell-by-cell basis. The figure 4.6 shows how to give conditions between two rasters. This can be done similar between a raster image and a constant.

c) Convert to integer: This step converts each cell value of a raster to an integer by truncation.

d) Form Factor: Form Factor is the shape measure that compares the area of the polygon with the square of the total perimeter. The form-factor value of a circle is 1, and the value of a square is π/4. These conditions are given as threshold factor.

$$\text{Form factor} = (4 \times \pi \times \text{area})/(\text{total perimeter})2 \quad (3)$$

B. *Accuracy Asseessment*

The accuracy of the extraction result was assessed using the planning map as the ground truth. The resulting building image was compared with a rasterized planning map. The evaluation measurements used were widely accepted for building extraction (Lee et al., 2003; Shufelt, 1999), which categorized all pixels into four types as a result of comparing two images pixel by pixel.

1) *True positive (TP):* Both the extraction and the reference indicate that a pixel belonged to a building.

2) *True negative (TN):* Both the extraction and the reference indicated that a pixel belonged to the background.

3) *False positive (FP):* The extraction incorrectly identified a pixel as belonging to a building.

4) *False negative (FN):* The extraction did not correctly identify a pixel that truly belonged to a building.

$$\text{Branching factor} = FP/TP \quad (4)$$

$$\text{Miss factor} = FN/TP \quad (5)$$

$$\text{Detection percentage} = 100 \times TP/(TP + FN) \quad (6)$$

$$\text{Quality percentage} = 100 \times TP/(TP + FP + FN) \quad (7)$$

V. RESULTS FOR SAMPLE DATA OF NIAGARA

A. *NHM*

Figure 5. NDSM or NHM

B. *Removal of Trees*

Urban trees tend to be confused with buildings because of similar heights of trees and low-rise buildings. To extract the buildings first the trees are removed as shown in figure.

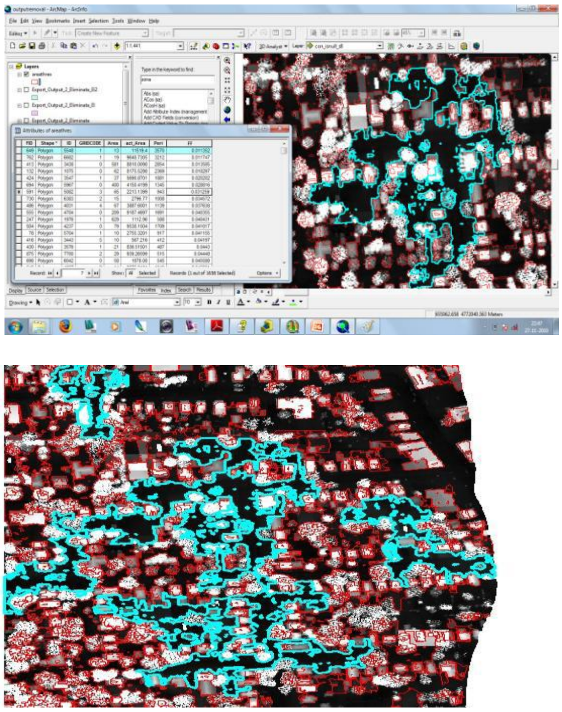

Figure 6. Tree Reduction by Threshold and Parameters

C. Building Extraction

The obtained result confirmed the assumption that in the image obtained by first refection point's interpolation there are more elements other than buildings that protrude above the terrain, most often these are trees. Whereas in the set of points from the last reflection, trees are eliminated to the sizeable extent, last reflection or return is taken shown in following figures

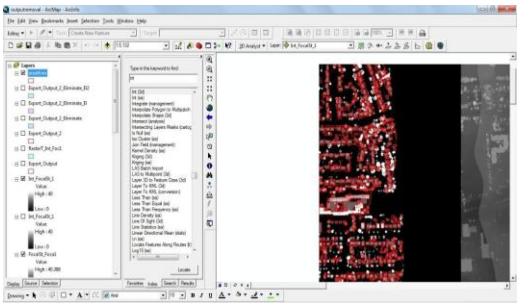

Figure 7. Building Extraction Done using ArcGIS Shown for Large Area

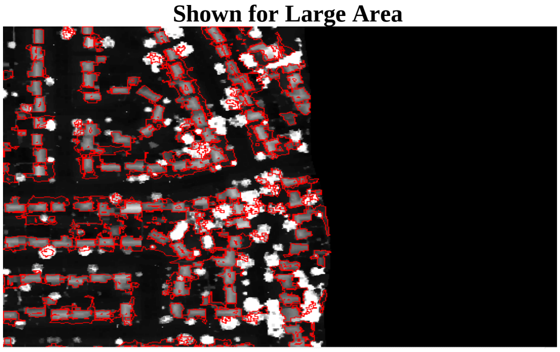

Figure 8. Extraction of Building

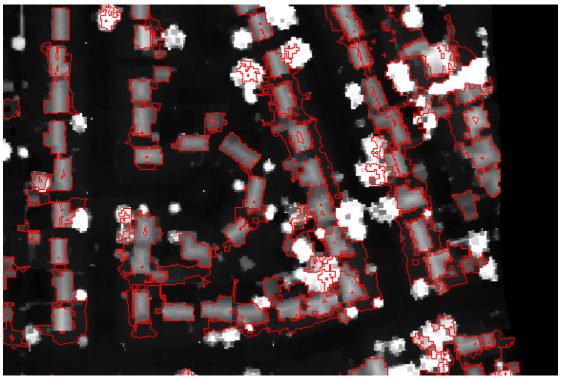

Figure 9. Minimum Number of Trees with Extraction of Buildings

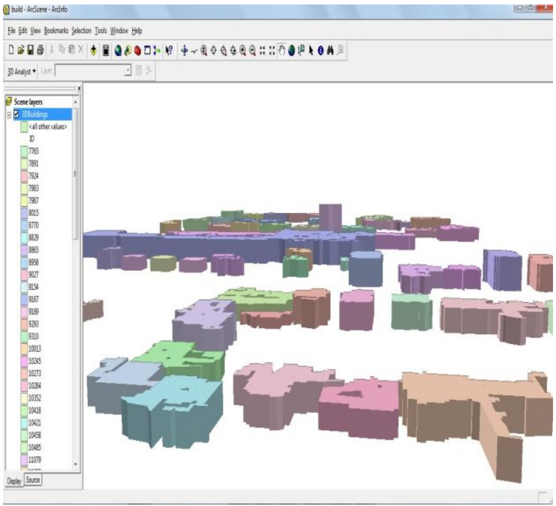

Figure 10. 3D Building of a Small Area

VI. CONCLUSION AND FUTURE WORK

In this work, the building extraction has been completed with certain threshold condition. Again, further conditions and edge detection algorithms can be used for better results. The 3D urban Modelling (built up) is developed for sample data of Niagara. This concepts is used to develop 3D for Chennai data is in progress to be analysed in the work.

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