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USE OF LIDAR DATA FOR FORESTRY APPLICATIONS

BY

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Abstract. LIDAR is known to be the ideal technology to obtain data on tree delineation and tree height over large wooded areas due to its high accuracy and the ability to receive data for vegetation areas. The use of LiDAR data, both in discrete form and on continuous form, is centered on the determination of biometric parameters, such as tree height and crown dimensions at tree level, at sample or individual tree level. This article presents the steps of ArcGis-based Lidar data conversion, as well as the interpretation of Lidar data, the process of determining a digital elevation model (DEM) and digital surface model (DSM).

Keywords: LIDAR; ArcGis; geodatabase; DEM; DSM; CHM.

1. Introduction

ArcGis can be used to analyze and manipulate Lidar data, giving the end user a useful result. This article presents the following steps: how to check the data provided, how to read and classify a cloud of points, create a visible cloud surface, analyze the field data set to delineate tree height, and crown density.

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The Airborne Laser Scanner (ALS) and Airborne LiDAR is an active remote sensing system used in a wide variety of fields (topography, hydrography, architecture, archeology, oil, mining, and forestry) over a decade. One of the advantages of the Laser Lane Scanner (LSA) compared to aerial photogrammetry or high-resolution satellite optical data is to capture high-precision 3D data by polar coordinates (inclined angles and angles) to obtain terrain geometry.

The first laser system (Light Amplification by Stimulating Emission of Radiation or amplification from lumière par stimulation of rayonnement emis) arose during the 1960s when German researcher Theodore Maiman discovered that light wavelengths of light can be separated and concentrated. This technology began in the 1970s and 1980s in Canada and the USA. Initially, experiments started with a near-infrared laser in impulse mode.

The recent discovery of LSA systems is so-called Full Waveform Digitizing (FWD). These systems provide a much more detailed description of the object structure, perform more accurate distance measurements, and allow extra detailed information on the signal by decomposing it into a series of reflections, *e.g.*, the "reflection width" expressed in nano seconds or amplitude.

Applications of these systems include: tree structure analysis, ground vegetation, discontinuity and slope tracking detection, etc.

In the forestry field, the first research on the use of LiDAR technology began in 1982 and aimed to obtain forest profiles using laser altimeters. More convincing studies emerged between 1984-1985, along with the development of other technologies and storage and data processing capabilities. Ten years later, with the introduction of computer systems with special applications, high-impedance scanners have also been used in forest measurements, and they can analyze multiple turns from the same pulse. In the same period, the first algorithms for measuring dendrometric elements and estimating the derived ones appeared. By the end of the 1990s, the possibility of obtaining data on forest inventories and topography of land using LiDAR technology became of great interest to forest managers (Nelson et al., 2003). With the use of high-speed pulse scanners and low-altitude platforms, LiDAR images can be reconstituted from the cloud of points obtained as individual isolated or even massive trees, on which direct determinations can be made look at the dendrometric elements. Furthermore, the resulting cloud image can provide tree tree information needed to identify the species.

2. Description of Data and Research Mode

Before being analyzed, the Lidar data is verified. Lidar data can be in the LAS format created by the American Society of Photogrammetry and Remote Sensing or ASCII. Point File Information Tool, found in ArcGis's 3-D Analyst toolbox, is an important tool that generates information about Lidar data. The tool is designed to read LAS headers or scanned ASCII files and summarize the contents of the file. A single file often contains millions of points, and many lidar data sets contain more than one file.

Point File Information Tool can read one or more files.

Las to Multipoint allows the user to read the LIDAR data files by uploading them to the geodatabase. Many lidar analysis applications can perform detailed analysis of the lidar files, but only on individual files. Uploading lidar files to a geodatabase allows you to create a mosaic of the entire LIDAR data set, which can then be parsed by ArcGIS tools.

Mosaic Dataset is a new data model in geodatabase that allows you to create image collections and enhancements to be stored as a catalog with the option of associating metadata, dynamic mosaic, and dynamic image processing. Accesses as a raster dataset (with all dynamic processing options) or in the form of a catalog containing the fingerprints of the images and their metadata (ESRI).

The Table 1 is an extract of the specification and describes the classification codes.

Table 1

The Coverage Classes of the Land where the LSA Data is Divided

0	Never classified	9	Water
1	Unclassified	10	ASPRS
2	Ground	11	ASPRS
3	Low vegetation	12	Overlap
4	Medium vegetation	13	Undefined
5	Hight vegetation	14	Undefined
6	Building	15	Undefined
7	Low point / noise	…	…
8	*"Model Key Point"*	31	Undefined

Digitale Elevation Model (DEM) – Complex spatial modeling allows the analysis of spatial data containing altimetry. The digital terrain representation is termed the Digital Terrain Model (DTM) or the Digital Elevation Model (DEM).

Digital Elevation Models (DEMs) are a type of raster GIS layer. In a DEM, each cell of raster GIS layer has a value corresponding to its elevation (z-values at regularly spaced intervals). DEM data files contain the elevation of the terrain over a specified area, usually at a fixed grid interval over the "Bare Earth". The intervals between each of the grid points will always be referenced to some geographical coordinate system (latitude and longitude or UTM (Universal Transverse Mercator) coordinate systems (Easting and Northing). For more detailed the information in DEM data file, it is necessary that grid points are closer together. The details of the peaks and valleys in the terrain will be better modeled with small grid spacing than when the grid intervals are very large. Ground return multipoint feature class shows Shape, Intensity, and Point Count fields (Fig. 1).

A digital terrain model (DTM) is also generated from points *x* and *y*, with *z* values representing elevations, but unlike DEM, they can be irregular or random dots.

The Digital Surface Model (DSM) Digital Surface Model (MDSR) is the elevation of the reflection surface of the upper crown of the trees, roofs of buildings and other elements on the surface of the field. By stealing from the digital model of the surface to that of the terrain, the Digitalized Model Surface Model (NDSM) Digital Model is obtained. Based on this, the heights of objects (eg trees or buildings) located on the surface of the ground are directly obtained.

Terrain is a nonlinear triangle network (TIN) – based on data sets that use feature class as data sources to model 3-D surfaces using the *z* values.

Creating a Terrain database is performed in the ArcCatalog environment by performing Feature Dataset. Geodatabase Terrain is the optimal format if altitude data sources include lidar points, being able to capture these multiple data sources in one uniform, easy-to-use surface. A land is not static and can be edited and updated as needed, so local editing can be done, and land restoration is done only for the editing area.

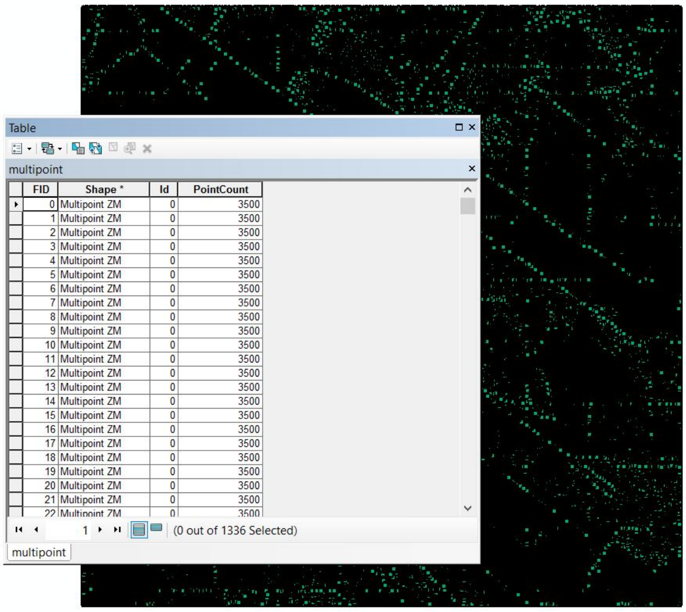


Fig. 1 – Ground points.

In forest applications, DEMs are useful for planning operational activities. DSMs define surface vegetation and are therefore useful for understanding the forest structure. DSMs identify stands with similar features and, when used together with a DEM, are used to calculate tree heights.

Lidar data gives the user the ability to create two distinct high resolution surfaces: a first turn or crown surface and a soil surface. Typically, DSM will contain tree crowns and buildings, and DEM will contain soil data.

The decision to build the geodatabase terrain or raster grid will depend on the requirements.

ArcGIS Server Image extension from Esri solves this problem.

To create the DEM, a method of making the pyramid can be used. If the data will be used for analysis, which is reasonable if the leader is subject to user needs, the tolerance filter z may be used. Although it is time consuming, this method is most appropriate (Fig. 2).

Field pyramids are generated by the point reduction process, also known as point thinning. This reduces the number of measurements required to represent a surface for a given area. For each successive pyramidal level, fewer measurements are used, and the precision requirements required for displaying the surface decrease accordingly. Source measurements are used in coarser pyramids. No sampling data or pyramid-derived data is used.

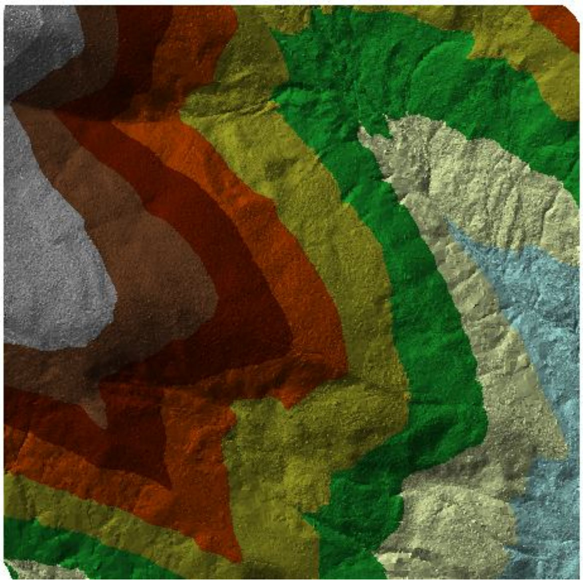
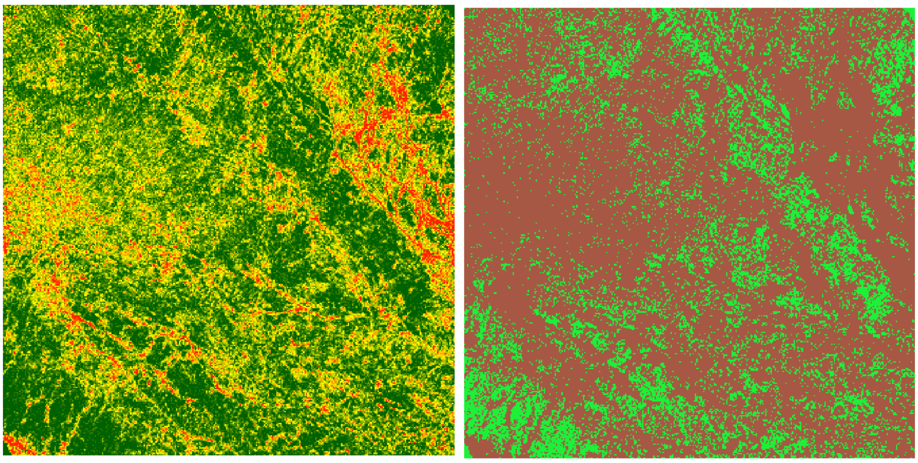


Fig. 2 – Terrain.

3. Create a DEM Raster

A DEM or DSM can be built directly from the multipoint point class using the Point to Raster tool. Point to Raster is ideal if the only data source is LIDAR data. The tool has a single class of input-like features, it is fast and produces results suitable for most forest applications. The disadvantage of this tool is that cells with the NULL value will appear in the raster where no return is found.

It is possible to reduce this effect by post-processing the DEM raster with a Python script that incorporates conditional (con) function. When using the conditional evaluation function, each cell in the DEM raster is evaluated for the NoData value. If the evaluation is true, then a filter is used to obtain the mean values of the cells around and applied to the NoData cell. If the evaluation is false, use the original raster (Fig. 3).



a *b*

Fig. 3 – *a* – DEM Raster created with Point to Raster; *b* – DEM raster postprocessing.

4. Calculate the Vegetation Characteristics of Lidar Data

Tree height estimation is useful for growth analysis and approximation of wood volume. Fast and slow growth areas can be quickly identified and fertilization systems have been developed based on these growth statistics. Both DEM and DSM generated by lidar data can estimate the height of a tree. To calculate the height of a tree, subtract one surface from the other by using the Minus tool found in the toolbox (ArcToolbox\Spatial Analyst Tools\Math\Minus).

Density of biomass will give indications about the tree and its growth. If a forest is of the same species, areas of low intensity can be quickly separated from high intensity areas.

To calculate the density of biomass, multipaths of soil need to be in one class of characteristics and all surface points in another class of characteristics. When creating the class of overhead features in the data, it is necessary to include all classes of vegetation. Vegetation classes are 3, 4 and 5.

The key to determining the biomass density is to calculate the raster file to be used with the correct cell size. Normally, cell sizes should be used four times larger than the mean point distances. This allows pixel mediation and NULL cell removal. If smaller pixel sizes are used, the frequency of NULL cells increases and may influence the results (Fig. 4).

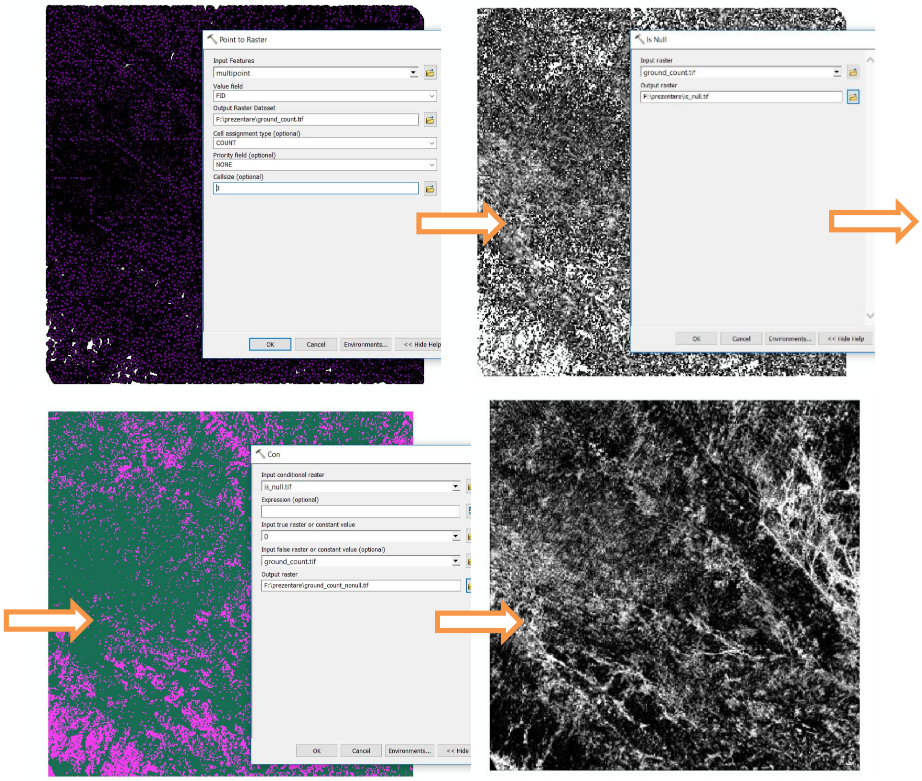


Fig. 4 – The process of obtaining the NULL raster.

4. Conclusions

The ability of LIDAR systems to provide height measurements allows us to find the vertical dimension of the stands. With this help, different methodologies have been developed for biomass extraction using both discrete-return systems and full-waveform LIDAR systems (Lefsky *et al.*, 2001; Bortolot & Wynne, 2005; Popescu, 2007; Edson & Wing, 2011). Discreet-retarded Lidar systems have a small footprint (typically 20,...,80 cm in diameter) and can record one or more crown turns depending on the laser energy return energy to the sensor. In contrast, wave sensors have traces of larger steps (10,...,100 m) (Evans et al, 2009; Lewis and Hancock, 2007).

This article has demonstrated that the benefits to the forest industry using LIDAR are wide and varied. These include methods such as: analysing and validating LIDAR data in the ArcGIS environment prior to any processing, storing and managing millions of LIDAR returns within the geodatabase within a set of data, regardless of the number of files, extracting DEMs and DSMs from LIDAR data and their storage in geodatabases or as raster files, the estimation of vegetation density and tree height, which helps with the analysis of growth, fertilization regimes, exploitation and additional operations, validation of traditional forest measurement techniques, serves and analyses large quantities of data for GIS customers, reducing the need to analyse each file, providing a general analysis of the forest.

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UTILIZAREA DATELOR LIDAR ÎN EVALUĂRI FORESTIERE

(Rezumat)

Lidar-ul este cunoscut ca tehnologie ideală pentru a obține date referitoare la delimitarea coronei şi înălțimii arborilor pe zone mari împădurite, datorită preciziei sale ridicate şi capacitatea de a primi date pentru zonele cu vegetație. Utilizarea datelor Lidar, atât pe forma discretă cât şi pe forma continuă, sunt axate pe determinarea de parametri biometrici, cum sunt înălțimea arborilor şi dimensiunile coroanelor la nivel de arboret, la nivel de suprafețe de probă sau la nivel de arbori individuali. Acest articol prezintă etapele convertirii datelor Lidar în format ArcGis, precum şi interpretarea lor, procesul de determinare a unui model digital de elevație (DEM) şi al modelului digital de suprafață (DSM).