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The New Lidar Classification Format: The Lal Format and Its Applications

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ABSTRACT: *Applications that require the use of LiDAR data and more generally of point clouds need, as well as powerful hardware to handle the massive amount of information, efficient software that can classify quickly and correct information geometry. After the downstream of classification operations, it is then necessary that the classified elements can be stored in formats able to retain the levels of information generated at the classification stage, in view of further analysis and technical applications. The present study intends to present an innovative storage format of classifications of LiDAR data, which allows to extend the possibilities offered by the usual LAS data, useful in the engineering nature applications.*

KEYWORDS *-LiDAR Data; LAS format; GIS*

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I. INTRODUCTION

LiDAR is a relatively recent technique that has entered the world of engineering applications in a very massive way.

For certain aspects similar to the radar, but using a different part of the electromagnetic spectrum (RADAR uses radio waves or microwaves, while LiDAR uses light at or near the visible spectrum, and typically aerial mapping LiDAR uses 1064 nm Yttrium-Aluminum-Garnet lasers), LiDAR uses the laser to illuminate a target and then analyzes the reflection. The narrow laser beam makes it possible to map objects with a high degree of resolution.

The basic technology has been around since the 1970s, but because of size, cost and complexity had limited application, but recent dramatic advances in laser and detection technology, computational speed, and memory storage have made commercial applications possible.

LiDAR systems allow scientists and mapping professionals to examine both natural and manmade environments with accuracy, precision and flexibility.

The uses of the LiDAR entered in multiple engineering applications. In the field of the aerial applications, we can include [1,2]:

- Mapping and Cartography, in conjunction with aerial photogrammetry, in road, building and vegetation mapping;
- Forestry Management and Planning, to predict canopy bulk density and canopy base height;
- Urban Planning, combined with digital ortophotos, to create highly detailed DSMs and Digital City Models;
- Flood Modeling, to solve the purpose that relates to the systems topography as well as to the identified features;
- Oil and Gas Exploration, where differential Absorption LiDAR (DIAL) can be used to detect trace amounts of gases in the atmosphere above hydrocarbon deposits;
- Quarries and Minerals, to determine air pollutants as well as surveying land around the area;
- Archaeology, to discovering underlying features that are otherwise hidden by vegetation;
- and then Geology, Coastline Management, …

In the field of the Ground-based LiDAR Mapping, we may consider:

- Architecture;
- Building Restoration, to capture minute details outdoor and inside of a buildings;

- Scene of Accident/Crime, to record the scene of an accident within a few minutes;
- Navigation, for the experiments for guidance system for autonomous vehicles;
- Visualization and Gaming, to re-create objects in a computer environment.

All the listed activities are based on fundamental classification techniques of LiDAR data.

The classifications are operated by means of filtering algorithms, often supplemented by manual finishing operations.

The LAS format does not allow permanent storage of performed classifications, and there is therefore no alternative to a duplication of the archives, to store different classifications.

The LaL format, however, allows you to store a number of thematic layers that are permanently stored within the file, so they can be viewed with software that can read this format.

Thanks to LaL it is clearly possible to extract a file in LAS format with a specific theming, as better explained in the following section.

II. INNOVATION IN THE LAL FORMAT

The information contained in the point cloud are a fundamental support for various branches of engineering, such as the civil one.

Standards for representing the point cloud has been implemented over the years: LAS, CSV, DXF, SHP.

CSV stand for "Comma Separated Values" and it's a human-readable format. The "data organization" on this file format is not ideal for achieving optimal computation target, but it's very simple to understand the information contained.

DXF file is a file format created from Autodesk. It can describe more features than a point cloud: line, arcs, areas and complex vector features. The format is intended for an advanced digitalization, not for managing a huge amount of points.

SHP is a file format created by ESRI: this represents the standard in GIS features.

The advantage of this format respect to DXF is the possibility to connect alphanumeric information to the entities.

LAS is the standard de facto for the representation of the point cloud. The ASPRS (*American Society for Photogrammetry and Remote Sensing*) is the organization that provides the definition [3]. It's structure let complex computation on the point cloud possible. This file format is point-oriented: only points can be represented. Similar to the SHP files, some attributes can be connected to the 3D information.

The LaL (***L***as ***a***ccess ***L***evel) format is intended to extend the standard capability of the Las format, providing (virtually) infinite information for each point [4-6].

The LaL format is based to the Las structure for the spatial indexing of the points, but it is not limited to it. Its goal is to create several *Levels* starting from the original Las dataset, with the target to decrease the size of the file without losing any information. Furthermore, the information on the VLRs has been extended to collect any type of information relative to each *tuple*.

The final result is a set of information split to several datasets, spatially and logically correlated, with the result of a fast and detailed indexing of each point, permitting to achieve fast searches on the attributes on the dataset [7].

III. LAL FORMAT DESCRIPTION

The LaL format is a set on *n-files*:

- 1 "seed" file containing the planar coordinates
- n-1 "leaf" file with proper information

Tuples are indexed in the LaL structure in a smart way: the record number of each tuple indexed from "*seed file"* is the same in the "*leaf*" file (KEY): that solution enormously decreases the size of the final dataset.

By the KEY, multiple information can be associated to the "seed" information. The header contains the basic information to handle the ''.lal'', which are:

- Seed or leaf dataset
- Inside type of information,
- Boundary box coordinates,
- Others (depending from the purpose)

The header provides the basic information to "rebuild" the ''las'' file. The backward compatibility is guaranteed by "recomposing" the seed + leaves files to the LAS standard structure, selecting the information compatible with the LAS format.

A fast query con be performed, in the LaL file, by the point order that is rearranged to allow a fast search. The size of the hashing table is described in the header and can be customized, but in general allows a speedup of

100x-400x with respect to the standard search on a non-indexed LAS file.
The structure of the LaL is planned to achieve fast query results on the point cloud; by the information contained in the smart header of the ''leaf'' the "search operation" is a low computational capacity step and provides results very promptly. In order to obtain a georeferenced information, the results of the query are linked to the "*seed file*" by a "unique-KEY" of each result.

IV. LAL FIELD OF APPLICATION: EXAMPLES AND CASE STUDIES

The primary goal of LaL format is to connect custom information to the point cloud, allowing the execution of fast queries. Adding information to a LaL file is very simple and intuitive: given a georeferenced dataset of information (raster or vectorial), this information can be associated to the points that intersect the source dataset, creating a new LaL with proper fields. LaLcan be used to handle information computed from the geometric 3D properties.

V. CASE STUDY 1: LAL FROM RASTER

The primary goal of LaL format is to connect custom information to the point cloud, allowing the execution of fast queries. Adding information to a LaL file is very simple and intuitive: given a georeferenced dataset of information (raster or vectorial), this information can be associated to the points that intersect the source dataset, creating a new LaL with proper fields. LaLcan be used to handle information computed from the geometric 3D properties (Figure 1).

In Italy, the environmental constraint maps have been often drawn based on a poor and obsolete dataset of information. Now, it is possible to extract sharp information using LiDAR surveys, and with a spatial join it is possible to check the quality of the original constraint map.

Target: Knowing the correlation between landscape protection, land registry and geometric information derived from the point cloud of a specified area.

Source:

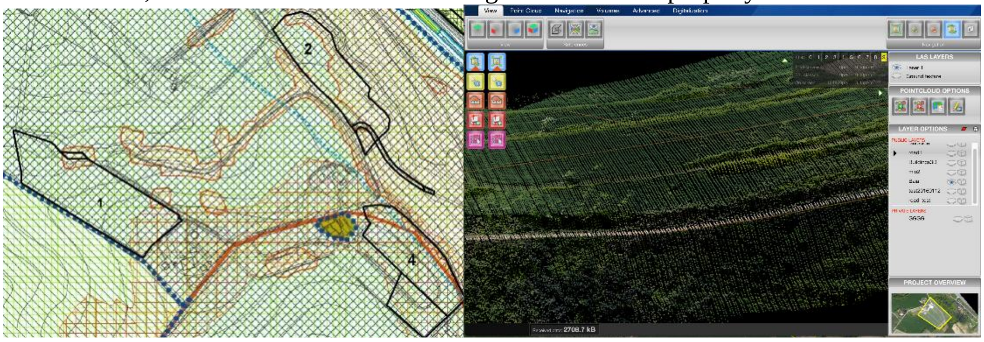
- Thematic map (PDF with levels, representing the slopes constraints)
- LAS coming from LiDAR survey (8pt/sqmt)
- Cadastral maps (SHP).

Methodology: in the beginning, every single PDF level has been transformed into georeferenced raster, subsequently, by a spatial join, it has been possible to create the LaL files describing the correlation between:

- Point cloud and the land parcel
- Differences between declared and computed slope maps
- Breakdown for each land parcel, the percentage falling in the environmental constraints

Output: **LaL**files: SEED, risk rating, percentages of constraints on each land parcel, slope for each persistent constraint on land parcel.

Goals: thanks to this analysis and by using simple queries, it is possible to cross validate the original raster with the updated information, evaluate the number of building associated to a property and check critical situation.



(a) (b)

Figure 1: the raster map **(a)** and the classified LiDAR data **(b)**

VI. CASE STUDY 2: LAL FROM VECTOR

Aerial LiDAR can detect sharp information of the 3D, but often the facade information is difficult to detect through an airborne survey. Dedicated devices can detect roofs and internal 3D point cloud (Figure 2).

Target: knowing the geometric characteristics (split per LaL) of the buildings associated to the properties.

Source:

- SHP files with cadaster information
- LAS coming from point LiDAR survey

- XYZ+RGB point cloud coming from ''Tango'' survey executed by a mobile phone Lenovo Phab 2 Pro/

Methodology: by a spatial join on the point cloud and the SHP files, it is possible to "connect" the building geometry to the information relative to the owner of the house.
Output: **LaL** files: SEED, building geometry, building property
The "attribute information" is derived from a spatial join with the information in the dbf of the SHP file.

Figure 2: the classified LiDAR data

VII. CASE STUDY 3: LAL DEEP CLASSIFICATION

Target: obtain a detailed point cloud classification of the Göttweig Monastery, detecting ground, vegetation, roofs and walls based on geometric properties and RGB information (Figure 3).
Source: LAS + RGB obtained with a drone survey (with the courtesy of RIEGL). Göttweig Monastery Survey performed through:

- UAV-based 3D Laser Scanning: RIEGL RiCOPTER + RIEGL VUX1 System
- Date of data acquisition: 16th February 2016
- Lower Austria, Latitude: N 48° 22' 4'', Longitude: E 15° 36' 45''
- Flight description:
- 2 flights: each approx. 20 minutes
- Recorded data: Monastery Göttweig + surroundings
- 1st flight: 12 strips
- 2nd flight: 6 strips
- Software: RiACQUIRE-Embedded

Figure 3: the flight plan for the Monastery Göttweig and its surroundings

Methodology: the LAS+RGB dataset has been loaded into PROMETEO, where has been achieved the pre-calculation of LaL dataset of RGB values, Height Above ground, normal values, 2 Density and 3D.
The classification routines using the LaL properties was based on:

- Ground: color, return number, geometric properties;
- Vegetation: color, numbers of returns, comparison 2D-3D density;
- Roofs: color, height on ground, comparison 2D-3D density;
- Walls: 3D density, normal values, geometric properties.

Output: LaLfiles: SEED, Height Above ground, Normal values, Density information, Wall classification, Floor classification, Roof classification, low Vegetation classification (Figure 4).

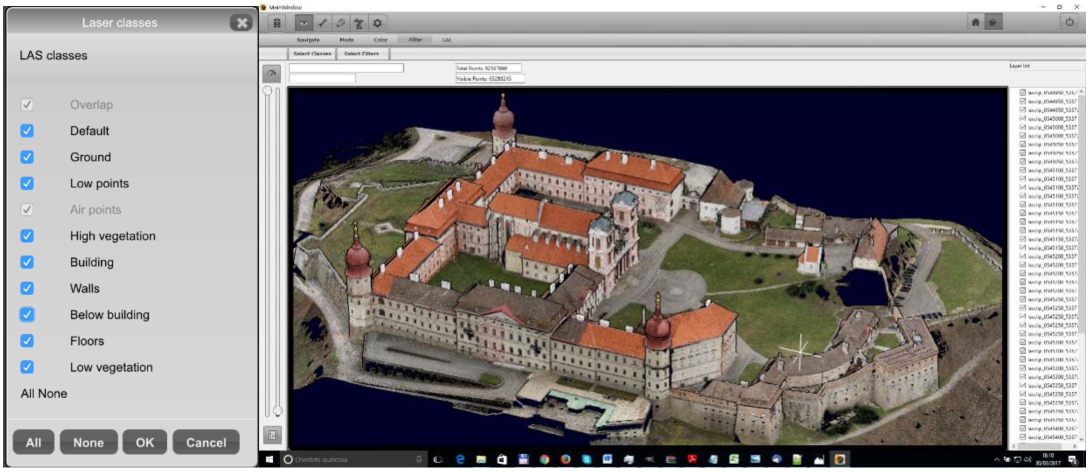


Figure 4: Monastery Göttweig classification (*Software Prometeo*).

VIII. USED SOFTWARES

LaL format is currently seen natively by the following software.
Clearly it is desirable to implement this format in specialized libraries for the management of LiDAR data.

Prometeo (MEDS BV)

Prometeo is the standalone suite developed by MEDS BV, Netherland (www.medsamsterdam.eu) that is able to create different set of LaL: it contains the algorithms to derive information by known property of the 3D dataset, and combine these for an easy use by a LAS exporting or by LaL publishing on *theAtlasGis* web service (Figure 5).

Promoteo has a free version that let the user:

- import point cloud;
- digitalize on the imported data;
- create LaL from imported raster and LAS;
- create 2D density and height on ground LaL;
- filter point cloud by LaL fields.

Advanced feature for *Pro* users:

- compute geometric properties from point cloud (3D density, normal values, echoes distances, and mathematical custom formulas);
- compute advanced classification from LaL properties;
- special functions, such as riverbed computation and GCP comparing;
- sync to www.theatlasgis.com the results.

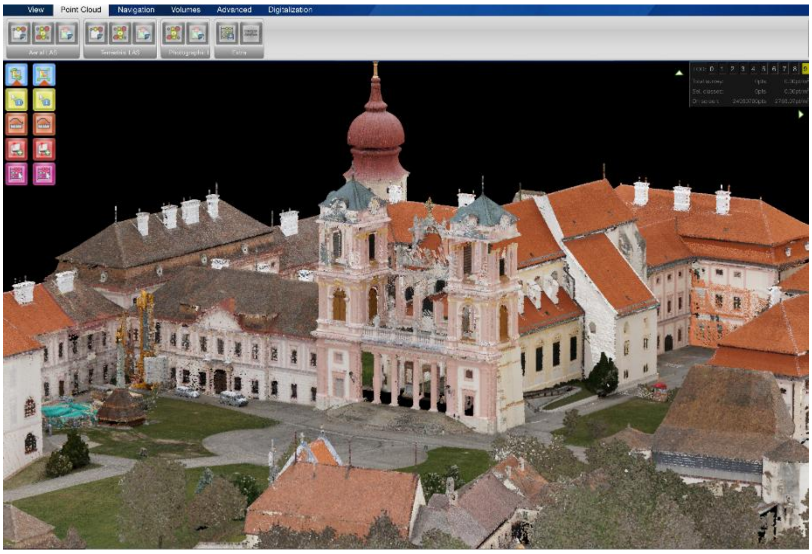


Figure 5: another view of the Monastery Göttweig classification (*Software Prometeo*)

TheAtlasGis (MEDS BV)

TheAtlasGis is a web service that streams over the Internet huge point cloud dataset by a standard browser. Its particular characteristics can be quickly covered with the vision of the following movie: https://www.youtube.com/watch?v=6I6VM2EfKZw

It is a very practical tool to perform preliminary designs and volume calculations, using all the information available from the point cloud, without any need to acquire specific software tools.

TheAtlasGis is able to download info in different file formats:

- TIFF, ECW, JPG
- XYZ, LAS, CSV, XLS
- SHP, DXF, KML

to relate to 3D databases through:

- spatial queries
- sections and profiles
- 3D point clouds

to compute advanced analysis for:

- 3D volume comparison
- flood estimations

and more…

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