Title:

Implementation and Optimization of a complete process of Collection, Classification and Exploitation of LIDAR data.

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SUMMARY

This report details an end-of-studies internship conducted at Topo Air-Tech, a French company specializing in aerial data acquisition and analysis, from February 28 to August 26, 2022.

With the goal of staying competitive in the face of new market requirements, the company sought to develop its LIDAR component, but faced challenges with processing time, data classification, model precision, and overall service quality.

To address these issues, the project involved an analysis of existing LIDAR point processing methods, followed by a phase of comparison, of classification and data exploitation tools. The end result aimed to implement and optimize a complete process of collecting, classifying, and exploiting LIDAR data.

With flight mission organization optimization being the first step, followed by standardization and automation of LIDAR point cloud processing and classification, and finally data exploitation to meet customer requirements. Through a comparative study of software and tools, choices were made based on specific criteria for each type of processing, with a focus on finding the right sequence of routines for task automation in a macro.

I. INTRODUCTION

In 2021, the company made a strategic investment in a LIDAR-equipped UAV with the goal of improving data quality and expanding market share. However, after a few months of working with LIDAR data and responding to market demands, the company faced significant challenges with processing and classification time, accuracy of models generated from processed data, and service quality.

To address these issues, and following discussions with the manager regarding existing needs and challenges, a 6-month final year project was undertaken to analyze existing LIDAR point cloud processing methods. This was followed by a research and comparison phase of classification and data exploitation tools, ultimately leading to the implementation and optimization of a complete LIDAR data collection, classification, and exploitation process.

II. STATE OF THE ART

I. LIDAR

A LIDAR is an electronic component that belongs to the family of sensors. More specifically, it belongs to the category of time-of-flight (ToF) sensors. A sensor collects data on a physical parameter such as temperature, humidity, light, weight, distance, etc. The acronym LIDAR stands for Light Detection and Ranging. It is a calculation method that determines the distance between the sensor and the target obstacle. A LIDAR uses a laser beam for detection, analysis and tracking.

II. Physical phenomenon

The LIDAR system emits laser pulses that reflect off objects both on the ground surface as well as above, such as vegetation, buildings, and bridges….

A transmitted laser pulse may return to the LIDAR sensor as one or more returns. Transmitted laser pulses that encounter several reflective surfaces on their path to the ground are split into as many returns as there are reflective surfaces.

The first laser pulse returned is the most important return and is associated with the highest feature in the landscape, such as a tree top or the top of a building. The first return may also represent the ground. In this case, only one return is detected by the LIDAR system.

Several returns are capable of detecting the heights of several objects in the laser range of an outgoing laser pulse. The intermediate returns, in general, are used for vegetation structure, and the last return for bare earth DTM models.

The final return does not always come from an earthly return. For example, imagine that a pulse hits a thick branch on its way to the ground and the pulse does not reach the ground in the end. In this case, the last return does not come from the ground, but from the branch that reflected the entire laser pulse.

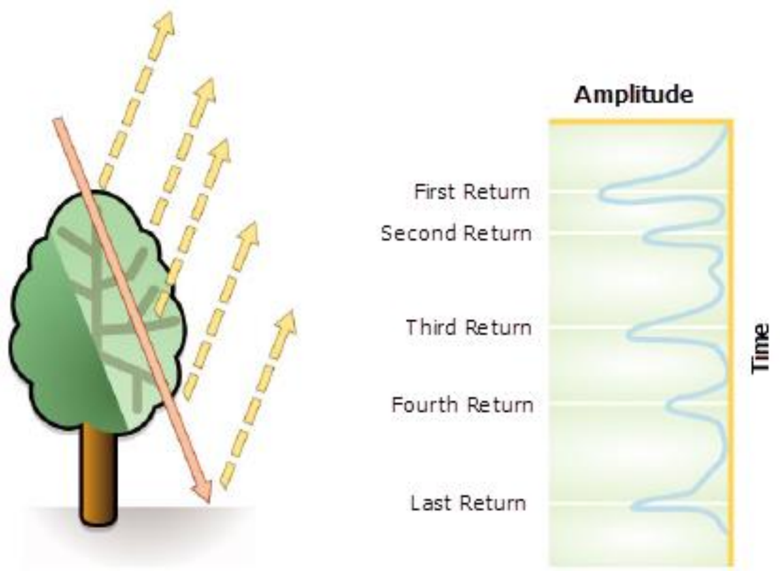

Figure 1: Explanatory diagram on the echo phenomenon

How it works

In the field:

- Emission of a laser pulse
- Recording of the backscattered signal
- Distance measurement (travel time x speed of light)
- Retrieving the position and altitude of the plane
- Calculation of the precise echo position

In the office:

- Reconstruction of LIDAR points
- Identification of LIDAR points
- Creation of 3D models

LIDAR for drones is a perfect match for:

- Small areas (<10km² or 100 km linear)
- Soil mapping with dense vegetation
- Inaccessible areas.
- Data needed frequently or in near real time
- High density (>150 pt./m²).
- Detection of small features in terms of surface or thickness
- Centimeter accuracy

III. Comparaison between LIDAR and photogrammetry

LIDAR and Photogrammetry are fundamentally different data collection methods.

LIDAR is a direct measurement: you physically touch a feature with light and measure the reflection. Drone photogrammetry uses images captured by a camera mounted on a drone to reconstruct the terrain in an accurate 3D model using sufficient image overlap and ground control.

With LIDAR, you end up with thousands of data points that form a 3D point cloud describing the terrain in question. You'll need to incorporate color from separate data sets to turn it into something visually accessible.

With Photogrammetry, you end up with hundreds or thousands of images that need to be processed and stitched together to produce something valuable, whether it's a 3D point cloud or a map. 10 Cloud-based LIDAR processing is not as widespread or accessible as photogrammetry software. Which means you'll need to have a specialist on site who can turn that raw data into something usable.

Choosing LIDAR:

- Map difficult-to-access, complex, and overgrown terrain
- Capture detail on thin structures, such as power lines or roof edges
- Projects where detail and accuracy are priorities

Choosing photogrammetry:

- Contextual analyses that are accessible and require minimal post-processing and expertise
- Maps and models that are easy to understand for untrained eyes

— Data sets that require visual

III. GENERAL CONTEXT

I. Problematic

How can we optimize the process of collecting, processing and exploiting LIDAR data based on the comparison between the methods of organizing the flight mission through classification to the exploitation of these data with a view to minimizing the execution time while guaranteeing the maximum accuracy?

II. Proposed Solution

In order to enhance and determine the optimal parameters for organizing the flight mission for each study area, a comparative analysis will be conducted on various methods of processing LIDAR points using the TerraScan Microstation software. Furthermore, a comprehensive process will be established to automate the processing of LIDAR point clouds for each type of study area based on land usage.Materiels used

A. Matrice 300 RTK Drone

The Matrice 300 RTK drone is the latest professional flying platform from DJI. With 55 minutes of flight time, advanced artificial intelligence capabilities, 6-directional sensing and positioning, and more, the DJI Matrice 300 RTK drone combines high-performance intelligence with unmatched reliability.

B. LIDAR sensor

The DJI Zenmuse L1 is a LIDAR with a high-precision IMU and a 1-inch RGB camera on a stabilized pod. Combined with the DJI Matrice 300 RTK and DJI Terra, the L1 is a complete solution that will allow you to obtain real-time 3D data, efficiently capturing the details of complex structures and providing reconstructed models with the highest accuracy.

IV. ORGANIZATION OF THE MISSION

The organization of the flight mission is a mandatory step in all projects of aerial data collection, wheter done by plane, drone or helicopter. This step presents the technical planning of the flight mission to to fulfill client requirements, estimate project costs, and prepare logistics.

In LIDAR projects, this step is considered particularly critical since it has a direct impact on all subsequent phases of the process. As mentioned earlier, Topo Airtech employs the DJI L1 Zenmuse sensor and the M300 UAV in its operations.

DJI FLY is an application installed in the controller of the drone and downloadable on Android and IOS, it allows the users of the DJI drone to introduce the necessary parameters of the mission and it calculates the period, the density and other information necessary for the mission.

With this application the drone will be able to fly autonomously during the mission respecting the flight lines, height and speed defined in the parameters.

This chapter will provide an overview of the various parameters for organizing the flight mission, highlighting the significance of each parameter, its impact on the data quality, and suggestions for managing the parameters effectively. (DJI, 2021)

I. Define and carve out the study area

The definition of the study area is considered a crucial step in all surveying and geomatics projects.

In the case of a flight mission over a large area, it is advisable to divide each area into sub-areas corresponding to a flight time not exceeding 20 minutes (flight time with a pair of batteries), keeping an overlap area of 40% between the last line of the first block and the first line of the second block to ensure the continuity of point clouds between them.

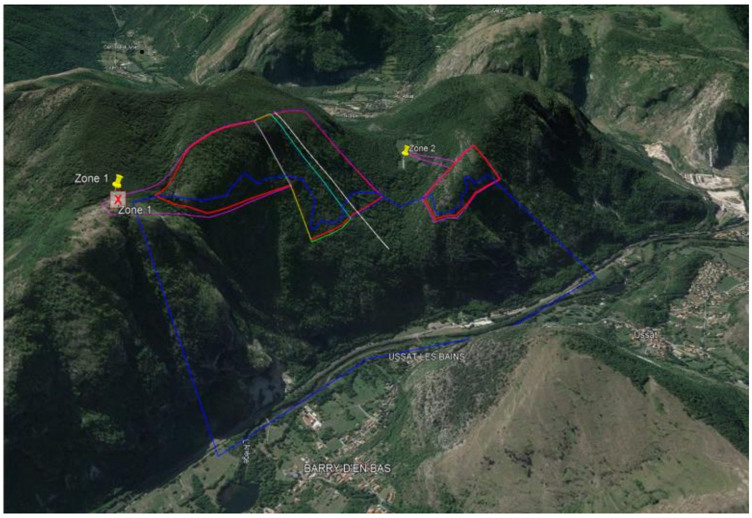

Figure 2: Delimitation of the project area with Google Earth

II. Define the flight parameters

After cutting the area, DJI offers us an application integrated in the controller of the drone called DJI PILOT, it allows us to enter the parameters of the mission (Height, Speed, type of scan, frequency ...) and it calculates the necessary information such as trajectories, time estimation, direction of flight lines, and density of points.

Based on this estimate, the field teams prepare the number of batteries, the necessary material and the necessary logistic equipment. (DJI, 2021)

A. Point cloud density

This parameter will be modified automatically after all parameters are entered, it depends on the flight height, scanning mode, frequency, speed and overlap area.

It is necessary to distinguish between the density of points and the quality of the points, one can have a high density but with a poor quality of response. (The quality is the percentage of points of the third echo compared to the total number of points).

Figure 3: Point density display

B. Terrain Follow & Select DSM File

Before the availability of this tool, geomatics and surveying companies avoided using the drone in mountainous areas because, on the one hand, the restrictions and laws oblige us not to exceed a certain flight height in each area and, on the other hand, we work in areas that contain differences in height that exceed three times or more the height mentioned in the codes of use of the airborne drone.

For these reasons, the acquisition of data with the drone was almost impossible. This tool is an innovation of DJI because it allows the drone to fly with a well-defined height from the ground even with the change of altitude of the terrain. (DJI, 2021)

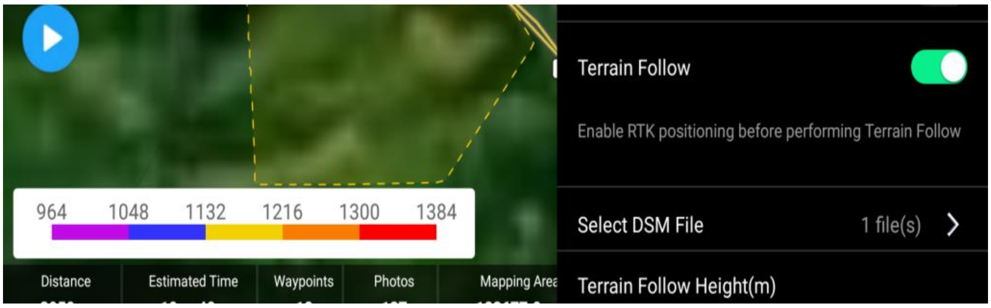

Figure 4: the Follow field mode activation

C. Speed (m/s)

The speed of flight is the parameter that determines the speed of the drone in flight, if we increase the speed of flight, the duration of the mission decreases, the density of the points decreases and also the quality of the data will be bad because with the increase of the speed the percentage of the points of the last response decreases.

The points of the last echoes have more chance to be ground points, for this reason it is necessary not to exceed 6 m per second. (Campany, n.d.)

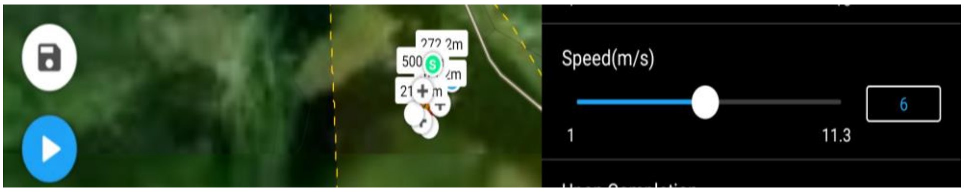

Figure 5: Setting the speed of the drone

D. Side Overlap (LIDAR) (%)

The overlap area is the percentage of overlap between the flight lines, the larger the overlap area the higher the density, the smaller the overlap area the greater the risk of having an empty area of points between the lines.

The choice of the percentage of overlapping area directly influences the density of the points and the time of the flight mission and consequently the number of batteries to be used.

Figure 6: Setting the percentage of the overlap area

E. Return mode

This parameter is considered the most important attribute and especially if we want to detect the ground, the L1 sensor offers us three modes:

- Single echo: The choice of this mode only if the customer wants a DSM.
- Double echoes: The choice of this mode if we have low vegetation and we want to generate a DTM, but this mode is not recommended to use.
- Triple echoes: The choice of this mode gives us more possibilities to detect the ground even with dense and high vegetation. (DJI, 2021)

Figure 7: the number of return echoes setting

Generally, we use the triple mode, and if we need only the first one we will process it later in the processing software.

F. Scanning mode

DJI zenmuse L1 gives us two scanning modes:

Repetitive mode: repetitive scanning provides a flat FOV, which is similar to traditional mechanical scanning methods. It can achieve more uniform and accurate scanning results compared to the traditional mechanical scanning method. (DJI, 2021)

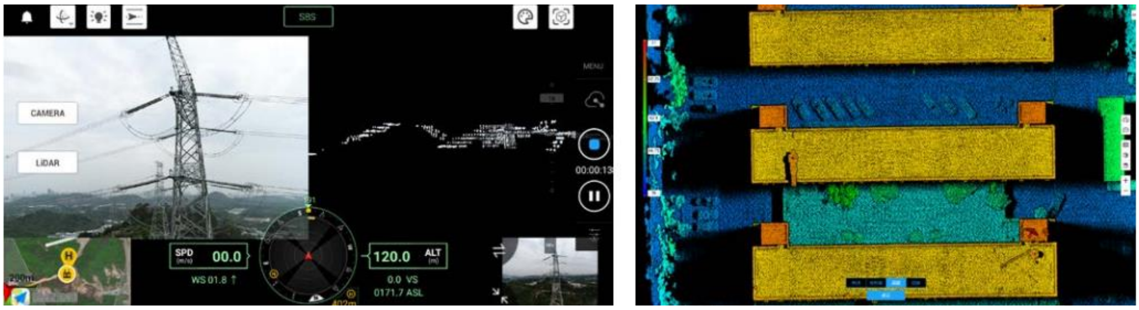

Figure 8: Data acquisition with the Repetitive mode

Non-repetitive mode: the non-repetitive scanning method is L1's unique LIDAR technology, it provides a near circular field of view with a denser scan density in the center of the field of view compared to the surrounding area, resulting in a more complete point cloud model.

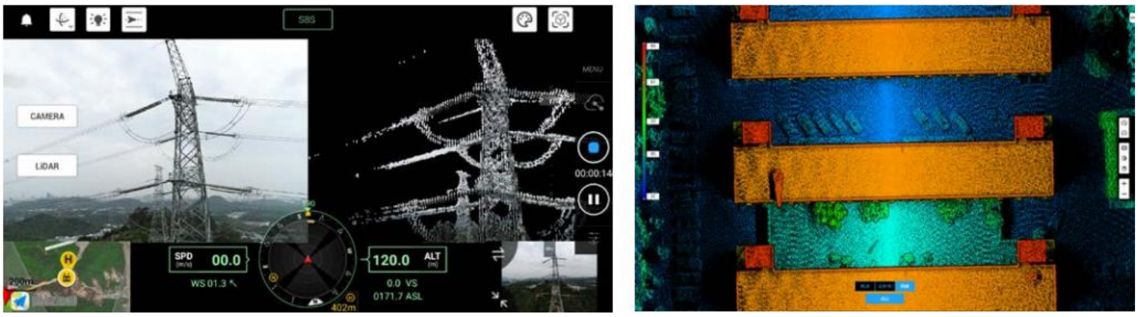

Figure 9: Data acquisition with non-repetitive mode

Conclusion

The organization of the flight mission is a determining step in all aerial acquisition projects. A good flight organization with a good parameterization will allow us to meet the customer's needs in time, on the other hand a bad data collection will take us longer and sometimes we have to redo the mission. We have tried in this chapter to present you the impact of each parameter on the quality of the data, all the choices and results are validated after research in the manufacturers' guidelines and dozens of tests.

V. CLASSIFICATION OF LIDAR POINT CLOUDS

This chapter presents the classification tools and methods available in the TerraSolid software package TerraScan, which is mainly dedicated to the management and processing of all types of point clouds (LIDAR, Photogrammetric or Terrestrial). It offers import and project structuring tools to manage the massive number of point clouds and the corresponding trajectory information.

The various classification routines allow the automatic processing and classification of the point cloud.

The management of points in this software is not limited to the execution of routines, it offers tools to create automatic and semi-automatic models that allow us to automate the process of classification and exploitation of LIDAR point clouds.

I. Routines

The diversity of the routines is one of the strong points of the TerraScan software, as there are more than 30 classification routines. This wide choice allows us to intervene using the available parameters to increase the quality of the classification.

II. Extraction of parameters

The extraction of parameters is an important and obligatory step in the process of classifying LIDAR point clouds, since it allows us to give the routines values that improve the identification of point types.

In TerraScan there are several tools for extracting parameters from LIDAR data citing: Measuring density, 3d view, horizontal and vertical profiles, measuring distances and surfaces ....

This information allows us to customize the processing models with the introduction of the necessary parameters for each area, we can say that this step.

III. Macros

TerraScan offers us a tool to automate the processing in the form of Macros. Macros provide a method to group together the routines and tools that process the point clouds to automate the classification.

They consist of a number of processing steps that are executed one after another. Processing steps can classify, modify, delete, transform, and generate points, as well as update views, execute commands, or call functions from other applications.

Macros are stored as files (.mac) that contain the names of the routines and the values of the parameters.

IV. General process of LIDAR point classification

Classification is the task that allows us to manage the point clouds so that they are usable, it consists of assigning to each point a specific class (soil, vegetation, water, buildings ...) in order to create models, curves or profiles that will be a basis for analysis in other studies such as hydrography, airport management, forestry management and natural hazards ....

In this section, the methodology for processing LIDAR points with TerraScan software on MicroStation in 6 different areas will be presented.

These results and methodologies were the result of several tests and researches to determine the most efficient process for each study area.

General classification process:

— Visualize in 3D the intense models, elevation model by color, model of colored points and representation of echoes to discover well the area of work and know the distribution of elements and details present in the area.

— Calculate the necessary parameters for the routines: slope, building area, point density ...
— Create a processing macro to automate the process.
— Manually reclassify the badly classified points.

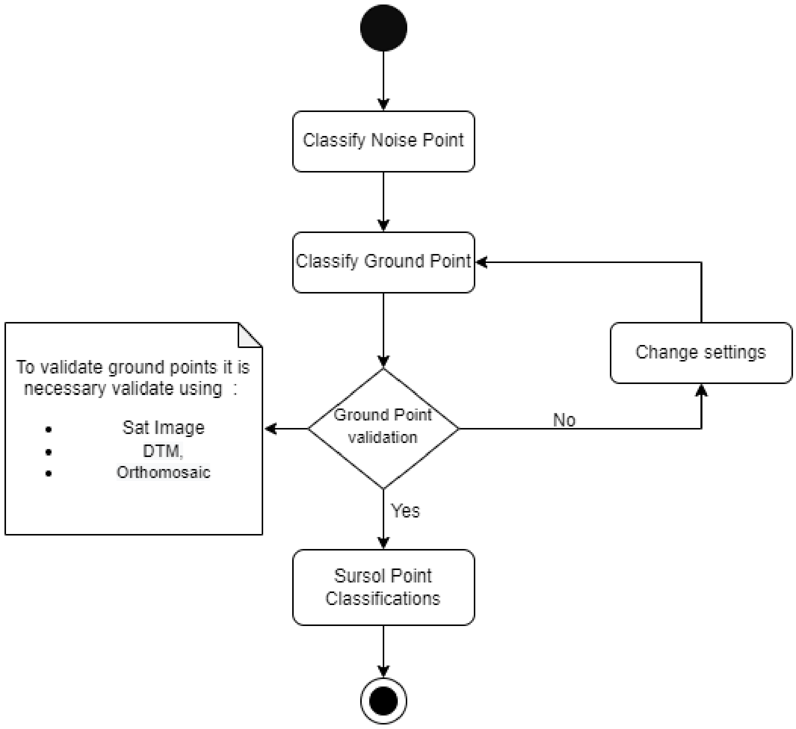

Figure 10 : General process of classification of LIDAR points

After the collection of data, a phase of treatment is mandatory for them to be exploitable, this treatment is customized for each area according to the details that exist in the study area.

V. Rural area classification

To create a process for processing and classifying LIDAR point clouds in rural areas we chose to work on an area with high and low vegetation to better evaluate our classification method, as presented in the Figure below.

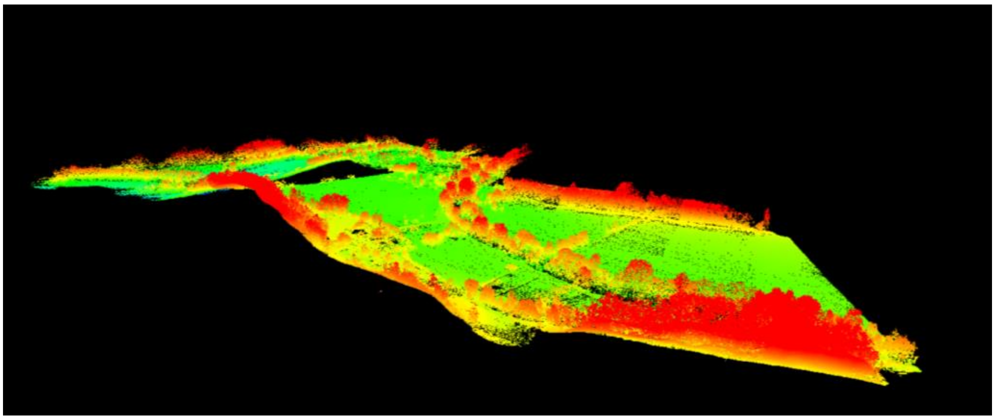

Figure 11 : Raw point cloud of a rural area

To create a digital terrain model that contains the planimetric and altimetric coordinates of the points every 1m, we must first remove the high and low vegetation and other details on or under the ground.

Before proceeding to the classification and creation of the macro, the first step as we saw in the beginning of the chapter is the extraction of parameters to enter in the classification routines, the parameters necessary for this treatment are the density of points and the slope. (TerraScan, n.d.)

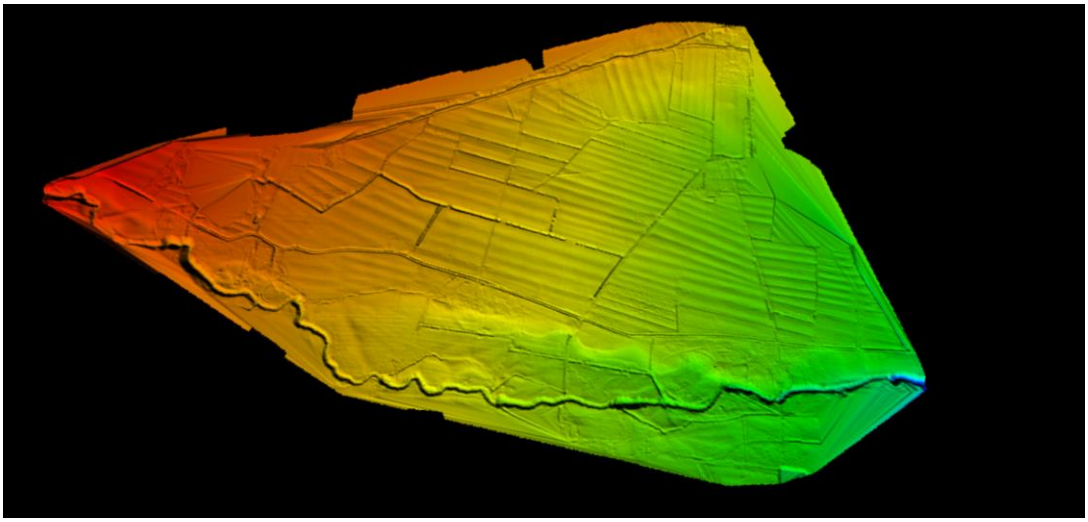

Figure 12 : Digital terrain model of a rural area

VI. Mountainous area classification

LIDAR is a technique particularly suitable for topographic surveys of heavily wooded, rugged or difficult to access areas, to create terrain models or surfaces in mountainous areas there is no other method better than airborne LIDAR.

It does not create problems of accessibility, accuracy or lack of detail or information because the laser waves emitted by the LIDAR sensor penetrate the dense vegetation and tall trees to the ground, which allows us to create accurate terrain models.

After a parameter extraction phase to automate the classification process, the next step is to organize the classification routines into a macro to meet the client's needs. (TerraScan, n.d.)

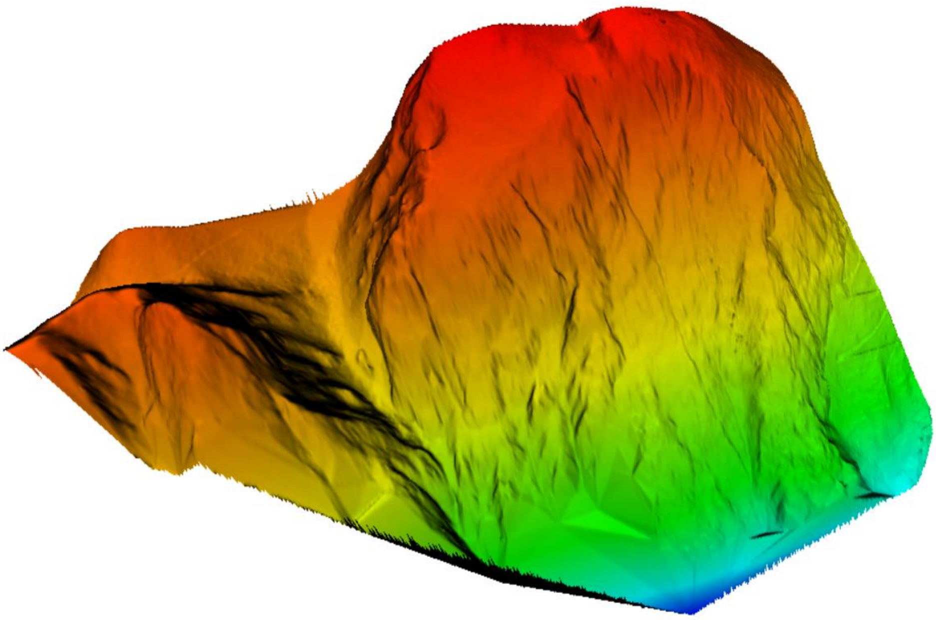

Figure 13: Digital Terrain model of mountain area

VII. Urban areas classification

The classification in urban areas is considered the most difficult and complex processing of LIDAR point clouds due to the diversity of details in the terrain, the majority of algorithms and tools available fail to identify the laser points in a correct way.

In this part of the report we will present the most efficient method obtained that allows us to minimize the manual processing of point clouds in urban areas.

As with all LIDAR processing, we start the processing by eliminating the noisy points to facilitate the classification of the next routines, before moving on to the classification of the ground points, a visual and statistical control is mandatory to evaluate the results of the routines performed. (TerraScan, n.d.)

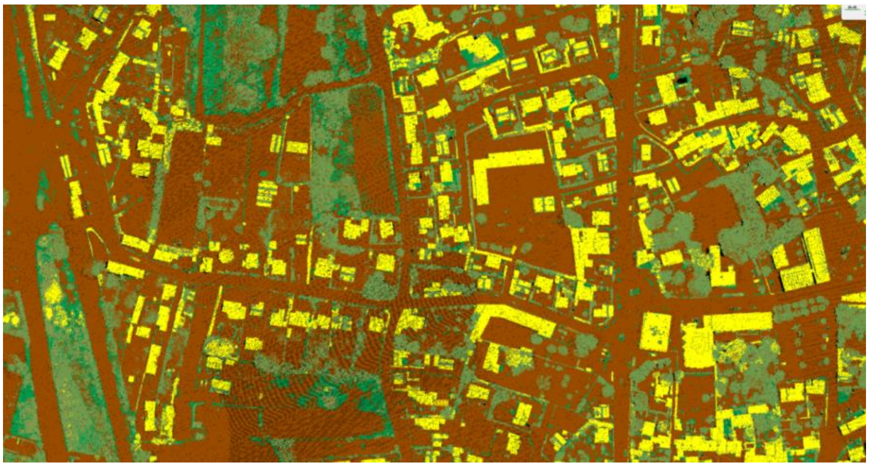

Figure 14 : Result of the classification of an urban zone

VIII. Power lines classification

The mapping of power lines and the creation of geographic information systems are of great importance in the management and maintenance of power and telecom lines. With the rapid development of urbanization and the increase of electricity and telecommunication consumption in recent years, spatial information plays a key and important role in decision making, location selection, and quick and effective intervention.

With millions of kilometers of cable, traditional observation and monitoring methods are no longer able to meet the needs of the market. Therefore, more automated and intelligent inspection methods are needed.

The level of development reached by LIDAR technology allows it to be used in power line monitoring applications. From the captured aerial point cloud data and appropriate software processing, the power line is easily extracted and generated as a 3D digital model. In addition, the LIDAR solution also provides rapid optimization and asset inventory capabilities required by the high scalability of the power line. LIDAR sensors support multiple echoes to capture the coordinates of the power line, electrical facilities, vegetation and ground objects in a single scan, significantly improving inspection efficiency. (TerraScan, n.d.)

Classification result:

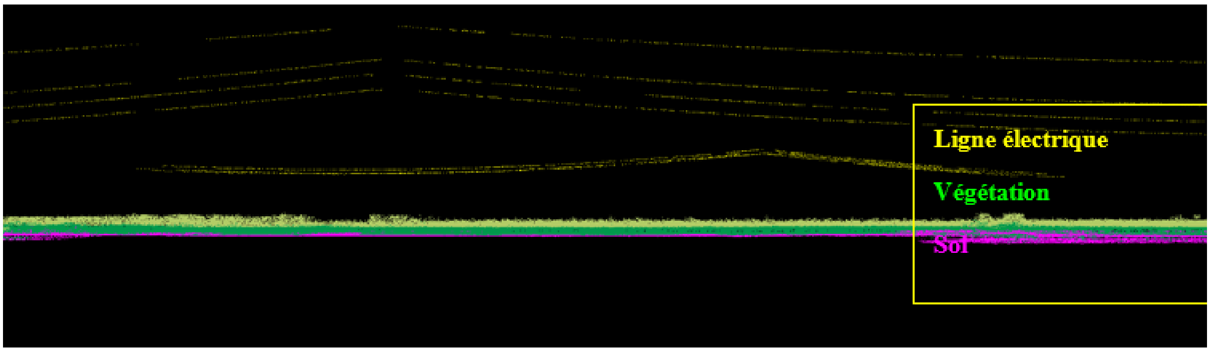

Figure 15: Result of the classification of power lines

Conclusion :

In this chapter we have presented the different methods of automatic classification of LIDAR point clouds in the following areas:

- Rural area.
- Mountainous area.
- Urban area
- Classification of power lines

All these methods have been presented in the form of activity diagrams to present the flow and logic of the processing macros, followed by a detailed explanation of the different routines used and the parameters to be introduced in each study area.

For a good presentation of the classification result, the next chapter will illustrate the different methods of exploitation of the processed data to meet the customers' needs.

VI. EXPLOITATION OF LIDAR DATA

After the two phases of data collection and classification, comes the last phase which is the exploitation of the processed data to meet the needs of the clients. In this chapter we will present the possibilities of exploitation of LIDAR data in the generation of:

- 3D cartographic product: DTM, DSM, contour line.
- The generation of 3d vectors of constructions.
- The distribution of LIDAR data in several formats according to customer demand.

This chapter also contains an evaluation and critique of the software and tools used, the limitations of the methods and the optimization of the choice according to specific criteria for each type of operation.

I. Digital terrain model

A digital terrain model (DTM) is a 3D representation of the surface of a terrain, created from the elevation data of the terrain. The DTM does not take into account objects on the land surface such as vegetation and buildings.

From the LIDAR point clouds the DTMs will be created after a whole process of classification of the point clouds, the DTMs will be created from the Ground class using the TIN method or other linking methods available in the software when using it.

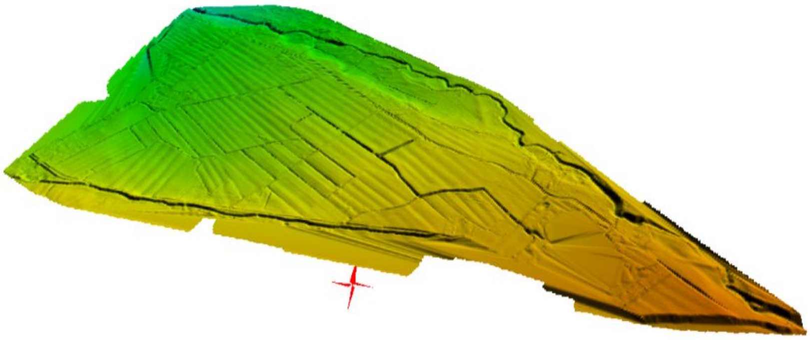

Figure 16 : Digital terrain model in a rural area

II. Contour line

The product "Contour lines" is a digital terrain model in the form of curves of the same altitude, also called "altitude isopleths", or more technically "isohypses", they are presented as imaginary lines (you will not see them on the ground) that allow to represent the relief.

To generate the contour lines you have to use the DTM or LIDAR points classified as ground points.

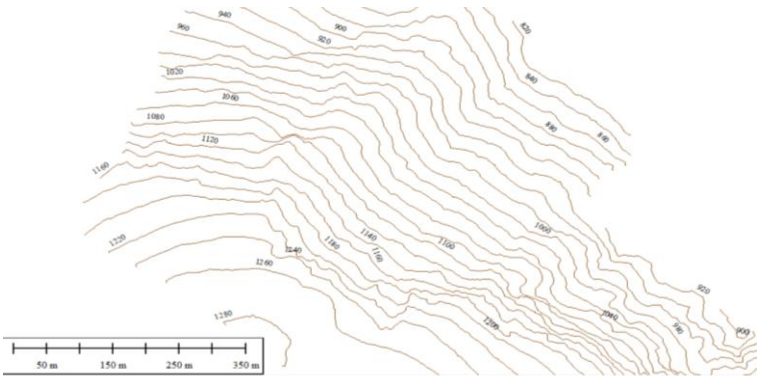

Figure 17: Contour lines

III. Digital surface model

An accurate representation of the terrain is essential for many land management applications. Digital terrain models (DTMs) and digital surface models (DSMs) are simplified representations of ground elevation. The DTM is a representation of the elevation of the "bare ground" without infrastructure, while the DSM reproduces the shape of the land surface by including all permanent and visible elements of the landscape such as soil, vegetation and buildings.

To create digital surface models from a LIDAR point cloud, only the first echoes should be taken, for more information on echoes in LIDAR waves, see the first chapter in the general concepts section.

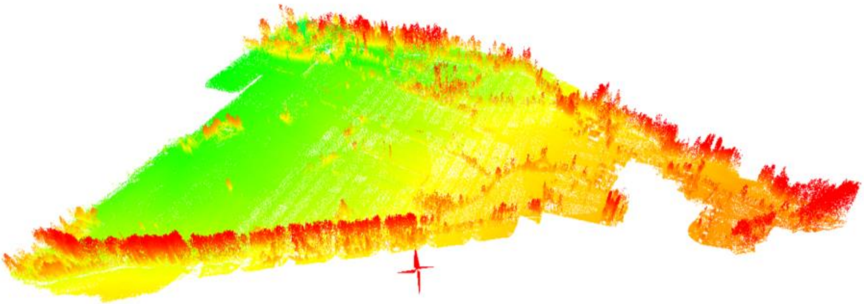

Figure 18 : MNS in rural area

IV. 3D vector

TerraScan provides a set of tools for the vectorization of buildings from airborne point cloud data (LAS or photogrammetric). The 3D vector models are created fully automatically, but for greater accuracy they can be manually modified with dedicated tools. These tools guarantee that the topology of a building model is preserved and allow quick and easy editing, the level of detail of this model is LOD 200 (Level of detail) which is predefined by TerraScan, it includes only the walls and the roof shape.

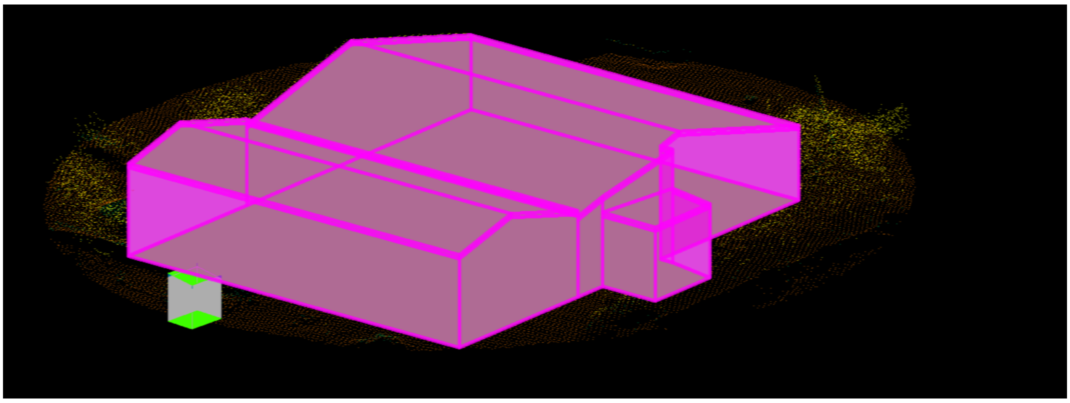

Figure 19: 3D building model samples.

V. Cross-sectional profiles

The cross-section is a representation of the surface defined by the set of points representing this surface by a section perpendicular to the axis of the road, river, dam, canal... The cross-section can refer to either the natural terrain or the project.

To create a cross-section from LIDAR points, we must first classify the ground points and then generate a DTM to create cross-sections with a centimetric accuracy.

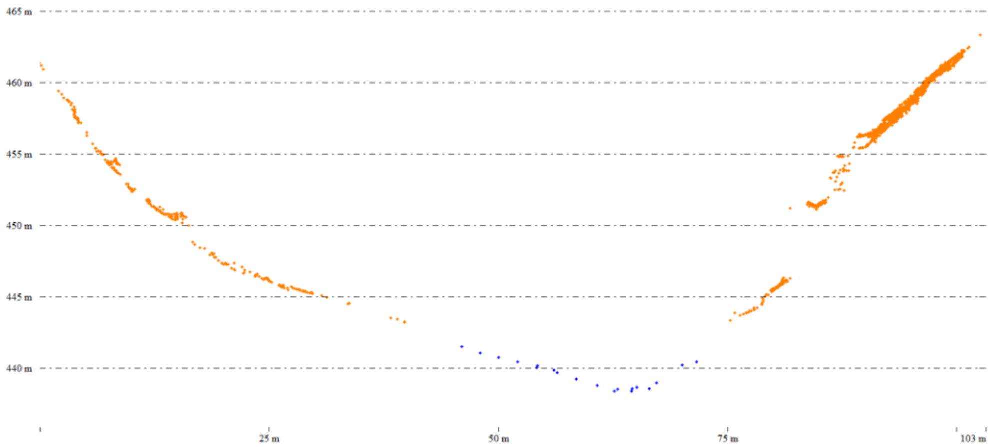

Figure 20 : Cross-sectional profiles from Bathymetric and LIDAR points

VII. CONCLUSION

After presenting the general concepts and framework of the project, and the workflow on LIDAR data, the results of six months of research, testing, optimization, development, innovation, and sacrifices are now available to answer the question of how to optimize the collection, processing, and exploitation of LIDAR data while minimizing the execution time and ensuring maximum accuracy through a comparison of flight mission organization methods, classification, and data exploitation.

The optimization of flight mission organization parameters, macro refinement in point cloud classification, and LIDAR data exploitation method improvements have enabled the company to focus more on LIDAR technology and engage in large data processing projects.

In addition to comparing software, methods, and tools, this study aimed to define the appropriate sequence for each processing step.

Despite Terrascan's efficiency in classifying LIDAR point clouds with its extensive range of routines and tools, we encountered shortcomings in the classification of overground features in urban areas. Nonetheless, our study demonstrated good performance in rural, mountainous, and forest areas.

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Mohamed Khalil Masmoudi, 25 years old, Geomatic and Topography engineer, I work in the TOPO AIRTECH company as LIDAR Data specialist, my main challenge is the development of LIDAR department specially the automatisation of LIDAR data classification in the way of reducing the processing time and develop the quality of results.

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