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ADVANTAGES OF REALISTIC REPRESENTATION OF A GEOGRAPHIC AREA BY COMBINING OPTICAL AND LiDAR DATA CAPTURED WITH UAVs

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Abstract

The paper aimed to present the advantages of realistic representation of a geographic area by combining optical and LiDAR data captured with UAVs. LiDAR data and aerial images, both captured with an UAV, have their own unique advantages and disadvantages and it is natural to integrate those two data sets for a good realistic representation of a geographic area in terms of horizontal and vertical accuracy. Compared with aerial images, LIDAR data provide more accurate height information but less accurate boundaries. Aerial images provide more extensive planimetric information such as high-resolution texture and colour information. Although 3D height information can be estimated from one or several images by the use of several photogrammetric methods, the height information extracted from aerial images is still relatively less accurate. The realistic representation of a geographic area in the virtual environment, was verified for validation in the Cernica Dam area, checking the spatial data sets used (LiDAR and optical). We used for data validation, the ground truth, given by GNSS measurements in the field, and the experimental results indicate that this combination improves the overall accuracy from 94% to 97%.

Key words: *LiDAR, mapping, photogrammetry, UAVs.*

INTRODUCTION

The use of Unmanned Aerial Vehicles (UAVs), named also drones, is still only in its infancy but with a rapid development in the last few years. UAV industry is still mainly dominated by start-ups. Unmanned aerial systems, composed by UAV + LiDAR + Digital Photo Camera + IMU + GNSS, constitute an increasingly important segment of engineering. Mapping and surveying drones provide an easy-to-deploy platform for aerial views of an area of interest. Currently there are some factors limiting the use of drones regarding operation time and development of regulation in many countries. UAVs contribute to the production of valuable 3D and image data for needs in various engineering projects, urban planning or scientific research.

As is well known, photogrammetry is a well-established technique for acquiring dense 3D geospatial information about objects and phenomena. In fact, the method is as old as modern photography, dating back to the middle of the 20th century. The science has continued to evolve over time, of course, and – especially in view of the recent advancements in computer vision and machine learning – the technology is no longer as simple as it may seem. Developers of photogrammetric software and equipment face the challenge of providing the mapping and surveying community with solutions that are sophisticated, yet also meet high customer expectations in terms of user-friendliness.

LiDAR (Light Detection and Ranging) technology is based on LASER (Light Amplification by Stimulated Emission of Radiation) scanning through the use of optically directed LiDAR beams to collect object information in direct 3D measurements. This allows the system trajectory (position and attitude), to be produced robustly and accurately. Prior to the mid-1990s years, GNSS-IMU technology was not affordable for commercial use. Since then, however, the market for devices has exploded, especially with the development of fibre-optic gyroscopes (FOG) and micro electro-mechanical systems (MEMS) technologies. Also, the build-up of nationwide GNSS base station networks has

contributed to the success of LiDAR in surveying and mapping in all its variety.
LiDAR, so effective in topographic mapping, makes possible the capability to direct 3D measurements to the target and penetration of the beam through vegetation to collect information from objects and the ground beneath. The light wave front passing through the vegetation produces information on the vegetation as a side product.
Dense and geometrically accurate point cloud offers photographic 3D capture of the reality for mapping, modelling and monitoring. Spectral information from LiDAR have significant implications on automated data interpretation (Wim van Wegen, 2019).
Keeping account of advantages and disadvantages of the two technologies, there is a growing tendency to combine them both (Table 1).

Table 1. Some applications which are using photogrammetry, LiDAR and both together

	Photogrammetry only	LiDAR only	Combination of both
Topographic mapping	60%	6%	34%
Cadastral Surveying	54%	19%	27%
Generation of DEMs	27%	46%	27%
3D City Models	30%	19%	51%
Agriculture	55%	18%	27%
Archeology	47%	9%	44%
Forestry	30%	26%	44%

More than half of the users rely on photogrammetry plus LiDAR for the creation of 3D city models, in agriculture, in archaeology, in forestry and others are also high-ranking applications. For example, in forestry, LiDAR-derived DEMs and photo-grammetric canopy surface measurements are both suitable for providing relevant geospatial information relating to forest canopy structure. Contrary to LiDAR, photogrammetry cannot penetrate vegetation canopy, but photogram-metric matching of digital aerial images is a cost-effective and reliable solution.

MATERIALS AND METHODS

The data collected by authors and used for the realization of the realistic representation of a geographical area were as follows:

- LiDAR point clouds obtained using UAV;
- Color digital aerial images taken with UAV;
- GNSS measurements in field checkpoints (GCPs).

The Flow Diagram (Figure 1), or otherwise the technological flow, is nothing more than a schematic presentation of the steps leading to the construction of the final product being analysed, which is the realistic representation of a geographical area.

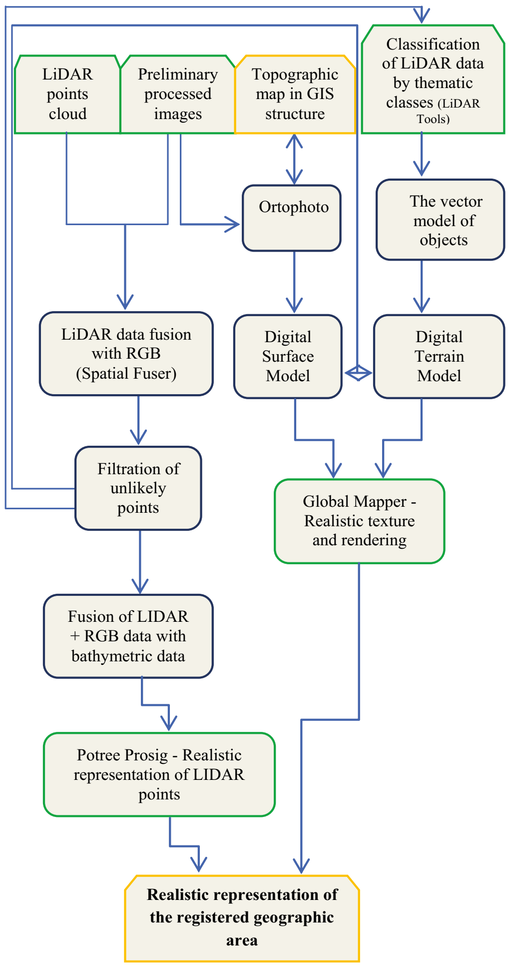

Figure 1. Workflow diagram to obtain the product "realistic representation of a geographical area"

The diagram presented is a review of all the steps that need to be taken when it is desired to obtain a virtual-realistic model of representing or monitoring an area of interest, such as those hard-to-reach areas, or areas for which a

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modelling realistic in particular of urban objects.

RESULTS AND DISCUSSIONS

Conceptually, the realistic representation of a geographic area is a new product that comes to the user with a reproduction of the analyzed area, in a digital format that is more in line with reality. The main use of the final product is to use it in various simulations of intervention in case of natural disasters, or even simulations of natural disasters (floods, earthquakes, fires, landslides, etc.).

The product, which can be generated entirely or only for certain thematic interest classes, is based on scanning techniques with the LiDAR-UAV system and the automatic and fast processing of data, all performed in accordance with the principles of photogrammetry. The product allows us to perform various types of measurements on the virtual image, determinations that reflect true field values.

The realistic representation of a geographic area, in our case in the Cernica Dam area (Figure 2), was made using: the point cloud LiDAR with RGB, the optical digital colour images and the digital topographic map in the GIS structure, the vector object model and the digital terrain model (DTM).

Figure 2. Cernica Dam area, chosen and tested for realistic representation

In the following Figure 3, several photographic pictures in the field and LiDAR point clouds from the model from the Cernica Dam area are presented for comparison.

Figure 3. In-field photographic images (on the left) and LiDAR point clouds in the model (on the right)

The realistic representation of the purchased LiDAR data is the merging of LiDAR data with the images recorded in the field. This method involves the generation of LiDAR point cloud with RGB merging the two datasets. Follow point cloud classification in grades points credible or anomalies. Upon completion of these processes, the generated point cloud is used in the realistic representation of the area with the Potree-Prosig application.

Optical data were recorded by the Sony A6000 camera, which was attached to the CPU and mounted on the DJI MATRICE M600 PRO as images with the ".arw" extension. This data format is a very professional one, representing the image to its maximum, uncompressed quality, but unfortunately this format was impossible to use in the next stages of obtaining a realistic representation. In order to be able to merge optical data with LIDAR data, these optical images were converted to ".jpg" format images using Image Converter. By using the same application, radiometric corrections can be made (correcting shadows or brightness too high).

The working mode in generating the realistic representation of the Cernica Dam area is checked using the Portree-Prosig software, as shown in the following figures.

Three ways in which a realistic representation of a geographic area can be achieved in the presented workflow (Figure 1), using the LiDAR and optical data purchased with the MATRICE M600 PRO - LiDAR SCOUT UAV system. These representations were made in the following way: the first is based on the geometrically and physically calibrated LiDAR cloud and pre-processed RGB optical images, the second was obtained from the RGB optical images and the topographical map in the GIS structure, and the third is a realistic presentation based on the collage made of two models (the vector model of urban objects and the digital model of the land).

In Figure 4, it is shown the transformation of the LiDAR point cloud in realistic representation for the Cernica Dam area tested for validation with the Potree-Prosig software.

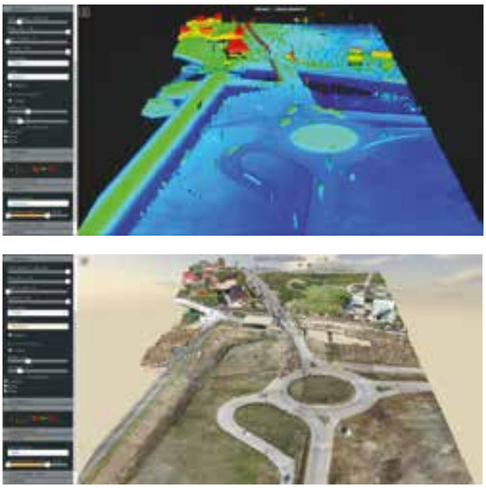

Figure 4. Transformation, with the Potree-Prosig software, of the LiDAR point cloud in realistic representation, for the Cernica Dam

For optical images, the final processing involves: obtaining preliminary oriented photograms using the Spatial Fuser application (using the camera file “.cam” and the navigation file “.nav”) and Agisoft PhotoScan Professional, orthorectification of images (correcting images based on 3D Mesh dense points), georeference (based on ground control points, determined at the data acquisition stage). All these steps, of the final processing of the optical data, lead to the obtaining of the georeferenced orthophotoplan (Figure 5).

For the “.las” file it was further elaborated: a data filter by extracting from the calibrated data set the unreliable points (those anomalies) by applying the integrated algorithms in the LiDAR Tools application, followed by an extraction of the digital models of the field (Digital Elevation Model) and surface function (Digital Surface Model) by using the same LiDAR Tools software, digital models shown in Figure 6 (for DSM) and in Figure 7 (for DEM).

Figure 5. Ortophotoplan for the verified area at the resolution of 5cm/pixel

UAV LiDAR and photogrammetry are both viable methods for capturing point clouds for 3D modelling of the ground or space-object in general. Although both methods produce point clouds, the manner of capturing data differs in many ways, resulting in point clouds with differing characteristics.

LiDAR is a technology that is based on laser beams. It shoots outs laser and measures the time it takes for the light to return. It is so called active sensor as it emits its energy source rather than detects energy emitted from objects on the ground.

Photogrammetry, on the other side, is a passive technology, based on images that are transformed from 2D into 3D cartographic models. It uses the same principle that human

eyes or 3D videos do, to establish a depth perception, allowing the user to view and measure objects in three dimensions. The limitation of photogrammetry is that it can only generate points based on what the camera sensor can detect illuminated by ambient light.
LiDAR uses lasers to make measurements, while photogrammetry is based on captured images, that can be processed and combined to enable measurements (Buczkowski A., 2018).

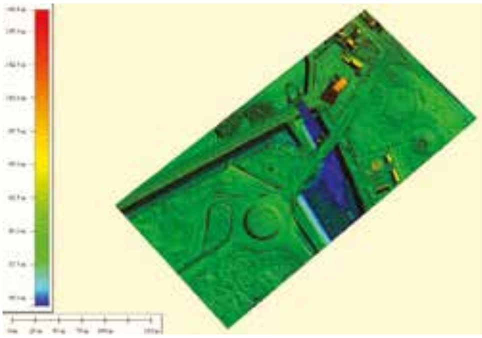

Figure 6. The Digital Surface Model (DSM) for the Cernica Dam area

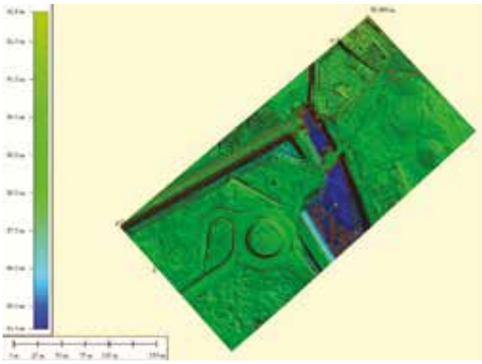

Figure 7. The Digital Elevation Model (DEM) for the Cernica Dam area.

The LiDAR and optical data fusion process was performed in the Spatial Fuser application developed by the Phoenix LiDAR integrator and delivered with the LiDAR system. The application uses the LiDAR Mill processed flight path, optical images converted to the ”jpg” format, the droning camera file, and the non-processed LïDAR file in ”ldr” format. Following this merger, a LiDAR point cloud with RGB color was obtained for each LiDAR point, the colour taken from the optical images (Figure 8).

Figure 8. Making realistic virtual model of the area after texture, in the Global Mapper

The final product, shown in Figure 9, was obtained by merging all the materials resulting from the previous stages (orthophoto and the cloud of points representing the ground points) and the realistic representation of a geographic area can be obtained in several variants of coordinate systems and data formats.

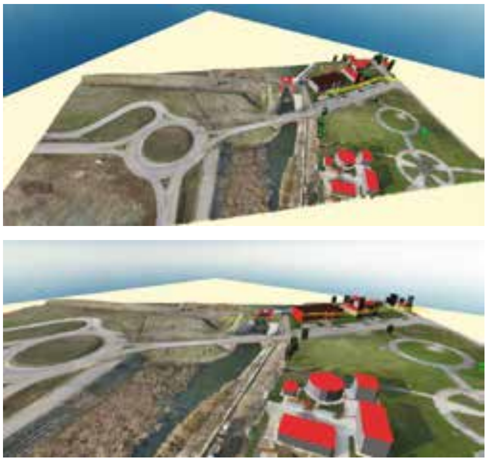

Figure 9. Making the realistic vectorial model using urban objects, DTM and the georeferenced orthophotos

The advantages of additional LiDAR surveying, face to photogrammetry, include:
(1) LiDAR provides a more accurate digital terrain model (DTM) when vegetation is present;
(2) LiDAR data can be processed faster than UAV photogrammetry and much higher productivity can be achieved;
(3) LiDAR is expected to produce better reliability than photogrammetry over weakly

textured surfaces (although a thorough data comparison still has to be performed to confirm this).

CONCLUSIONS

Data that is captured by either photogrammetric or LiDAR mapping technology is gathered in a point cloud. An often-heard question is whether photogrammetric point clouds are superior to LiDAR ones, or vice versa. The best answer is probably that there is no clear-cut answer; it depends on the application. Although LiDAR mapping may deliver a higher level of detail, photogrammetry is usually sufficiently detailed for large areas, for example. The fairest conclusion is that each system has advantages and disadvantages. Our research reveals that photogrammetry is a far more popular geodata acquisition technology for mapping projects than LiDAR (photogrammetry 75%, LiDAR 25%). However, the demand for LiDAR solutions is growing and LiDAR, in particular, is an often-used method for the generation of digital elevation models (DEMs). Our experimental results indicate that the combination of photogrammetry with LiDAR improves the overall accuracy from 94% to 97%.

Briefly, high accuracy in Photogrammetry is related to photo resolution, camera calibration, angles, photo orientation quality, photo redundancy and targets/marking precision.

Ease of use and low costs will make photogrammetry accessible to a wider range of users, including non-traditional photogrammetry users. There also seems to be a growing demand for software that is able work with LiDAR, aerial photography and UAV data in a single-window environment. In the future, it is very important to achieve the interoperability between data formats and/or sensor formats from different manufacturers and the rise of UAVs in the geomatics field will require new adjustments from providers of photogrammetric solutions.

The clear development trends are towards automated systems and real-time data processing. Also, longer operation times for UAVs are achieved with improved avionics, battery life and indigenous ideas for hybrid drones with 2-4 hours' flight time. Small but high-performance sensors and real-time data are the most relevant needs for drones, and typically limited project areas do not necessitate the presence of a GNSS-IMU. Data are processed to a local coordinate system using techniques prevailing within the robotics community. With ever-smaller and more capable GNSS-IMUs and decreasing prices, it happens that direct georeferencing reduces the effort for ground control.

3D mapping using photogrammetry and LiDAR has huge potential in many applications because data attributes are significantly discriminated and delineated with excellent accuracy and speed by involving limited manpower which is less time consuming and relatively economical (Ahmad Firoz et al., 2017).

The final conclusion of our study is the same with Aleks Buczkowski's: "When comparing LiDAR and photogrammetry, it is a key to understand that both technologies have their applications as well as limitations, and in the majority of use cases they are complementary. None of these technologies is better than the other and none of them will cover all the use cases" (Buczkowski A., 2018).

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