

Digital Terrain Model by airborne LIDAR technique: an essential tool for hydrologic risks assessment

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Simulations of the hydrological risks and thus the decisions of assessment strategies are crucial in the context of extreme meteorological events due to the consequences of the fast changes in the climate. The remote sensing methods as LIDAR backscatter technique are allowing the elaboration of a high precision (5 cm vertical and 3 points/m² horizontal resolutions) Digital Terrain Model (DTM) as basis of the hydrological modeling. Here is presented the airborne LIDAR technique, the usefulness of the DTM outputs for hydrologic applications and the potential application for the Romanian Danube Flood Plain assessment strategy.

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1. Introduction

DTM (Digital Terrain Model) is the start in analyse of the topology of the terrain but also for mathematical modelation and spatial data. This is a method for GIS (Geographical Information System) needed for simulations of the hydrological hazards.

DTM refers to a digital representation of a surface through elevation values.

LIDAR (light detection and ranging) is an active remote sensing system using a laser light (with wavelengths in range: UV, VIS, IR) to scan the target area.

The LIDAR technique is based on the detection and analysis of backscatter light that results from the interaction of a laser beam with target area (Fig. 1). Schematic, the LIDAR system is compound by a source laser and a receiver consisting in a telescope, an analysis/selection system and a photodetector.

A Lidar system emits pulses of laser light and precisely measures the elapsed time for a reflection to return from the ground below. Knowing the speed of light and the elapsed time, the distance to the target can be calculated.

This paper presents the airborne LIDAR technique, the usefulness of the DTM outputs for hydrologic applications and the potential application for the Romanian Danube Flood Plain assessment strategy into an ongoing project (i.e. REELD – Ecological and Economical Redimension of Danube Flood Pain).

2. Experimental

The airborne LIDAR technique includes a scanning instrument that generates laser pulses and detects the reflected returns, an on-board GPS to determine the geographic position and the height of the sensor and aircraft attitude measurement using an inertial measurement unit (IMU) to record the precise orientation of the sensor. A second GPS located at a known ground position receives data at the same time as the over flight for later differential correction of the on-board GPS data (DGPS), (Fig. 2).

By accurately timing the round trip travel time of the light pulses from the aircraft to the ground (water, foliage, buildings or other surface features) it is possible to determine the range with a precision of centimeters.

The airborne LIDAR systems can produce accurate measurements of surface elevation to digital elevation models (DEM) with a high precision (5cm vertical and 3 points/m² horizontal resolutions).

Using a rotating mirror inside the laser transmitter, the laser pulses can be made to sweep through an angle, tracing out a line on the ground. By reversing the direction of rotation at a selected angular interval, the laser pulses can scan back and forth along a line.

When a laser ranging system is mounted on an aircraft with the scan line perpendicular to the direction of flight, it produces a saw tooth pattern of ranges within a strip centered directly along the flight path, (Fig. 2).

The width of the strip covered by the ranges, and the spacing between measurement points, depends on the scan angle of the laser ranging system and the airplane height of flight.

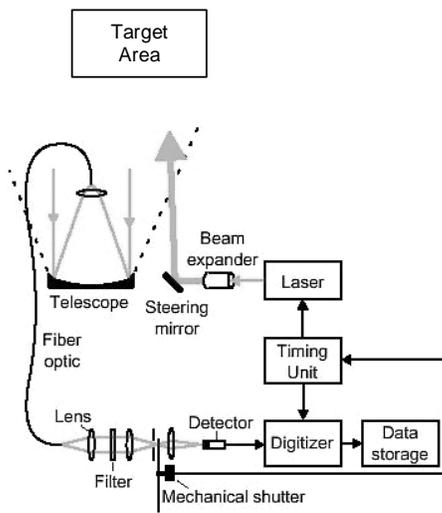


Fig. 1. Schematic of Lidar system.

These parameters can be selected to yield a measurement point every few meters providing enough information to create a Digital Terrain Model (DTM) adequate for most applications, including the mapping of flood damage to Danube alluvial plain, in a single pass.

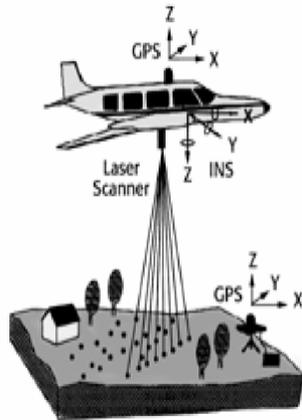


Fig. 2. Airborne Terrain Elevation Mapping Scanner System Outline.

After a flight the precise position of the aircraft at the exact period of each range measurement is computed relative to nearby GPS ground stations using phase differenced kinematics' Global Positioning System techniques.

As well as terrain data from DTM's LIDAR systems are capable of simultaneously recording the first return signal, the last return signal, or multiple reflections per pulse depending on the application. Not every pulse will generate multiple returns, and the number of returns will vary so the resulting data is in effect, a three-dimensional cloud of points.

Multiple returns can also be used to distinguish different land cover classes.

For this project it was used RIEGL LMS-Q560 scanner. The operational parameters can be configured to cover a wide filed of applications. The digitization feature enables the user to extract most comprehensive information from the echo signals. Fig. 3 explain a measurement situation where three measurements are taken on different types of targets. The red pulses symbolize the laser signals traveling towards the target with the speed of light. When the signal interacts with the diffusely reflecting target surface, a fraction of the transmitted signal is reflected towards the laser instrument, indicated by the blue signals.

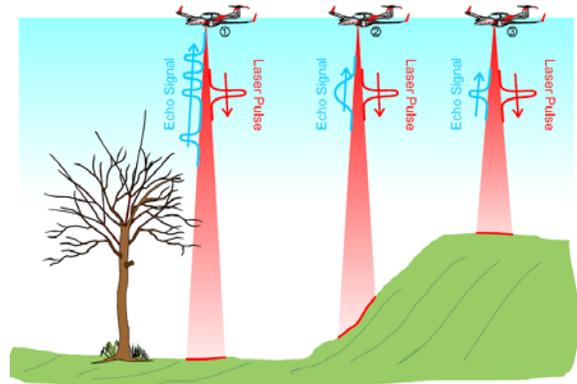


Fig. 3. Echo signals resulting from different types of targets.

3. Results

The dates were processed in Globe Mapper and ArcGIS 9.2 (using 3D Analyst and Spatial Analyst extensions), but also in Net Set (e.g. alternate software solution by Data Invest Iasi). The area that we interpret contains raw data from LIDAR within an area of approximately 1.07 ha.

In the train of these it resulted the following maps:

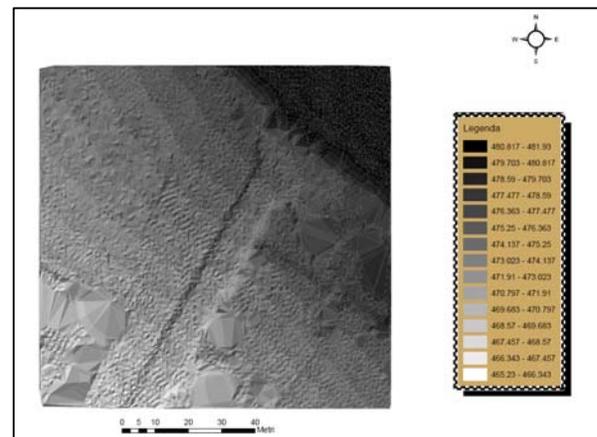


Fig. 4. Slope map (elevation).

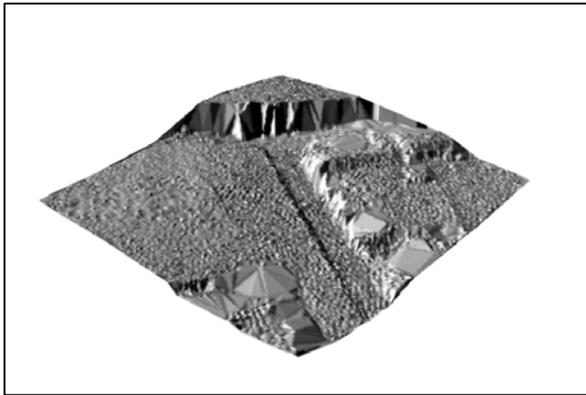


Fig. 5. Hill-shade map in 3D view (rotated right with 45 °).

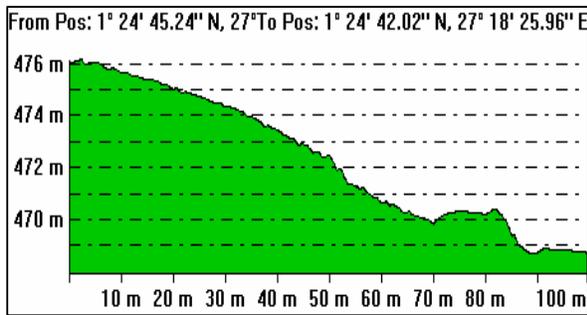


Fig. 6. Transversal profile to N-S direction.

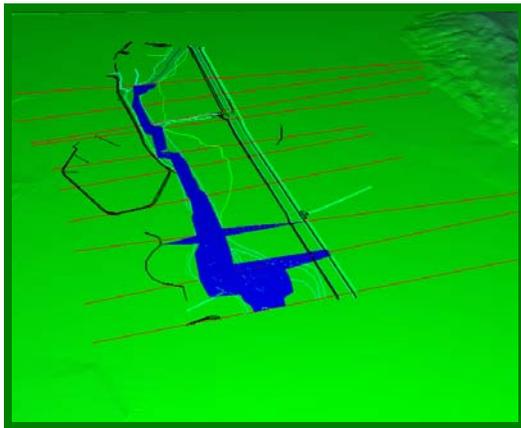


Fig. 7. Partial simulation for Siret River Basin study (1).

Some datas could be interpreted in detail and simulated using different GIS software (i.e. NetSet platform from Data Invest Iasi).

As we can observe in Fig. 7-10 for the Siret River we conducted a simulation in case of hydrological risk. This is also named hydrological risk modeling.

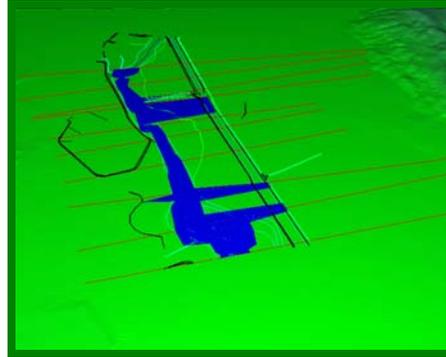


Fig. 8. Partial simulation for Siret River Basin study (2).

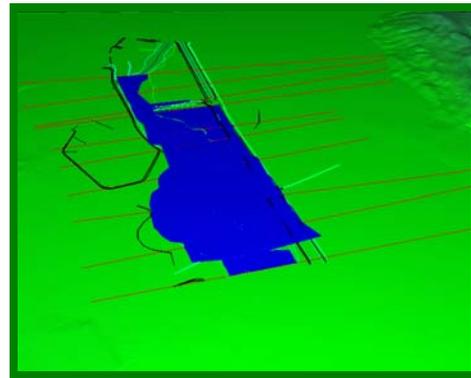


Fig. 9. Partial simulation for Siret River Basin study (3).

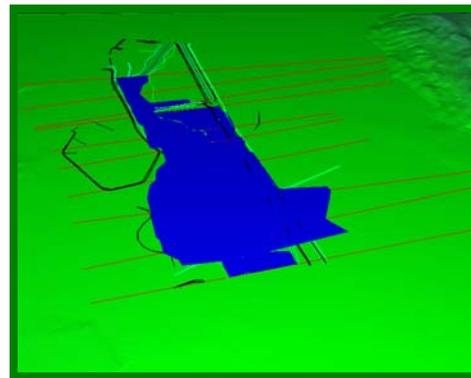


Fig. 10. Partial simulation for Siret River Basin study (4).

4. Conclusions

LIDAR technique is a state of the art technique, very accurate regarding to other methods used to elaborate a precise DTM (for ex. classical digitization on topographic maps).

With raw data from LIDAR, we could extract very important information such as slope, aspect, contour, profiles, etc. Here, we focus on the commonly slope map, hill shade map profile and in the end on hydrological risk modeling.

In conclusion, using a LIDAR technique correlated with a high GIS platform we can easily predict, model and even emit hydrological forecasts.

Therefore, this technique is very useful in the establishment of hydrological risks on Danube River (our case study).

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References

- [1] W. E. Carter, R L Shrestha, 2000, A Special GeoImaging Feature Submission, Department of Civil Engineering, University of Florida & S P Leatherman, Laboratory for Coastal Research and International Hurricane Center, Florida International University.
- [2] Ioan Balin, 2004, Measurement and analysis of aerosols, cirrus-contrails, water vapor and temperature in the upper troposphere with the Jungfraujoch Lidar system, Lausanne, EPFL.
- [3] J. F. O'Callaghan, D. M. Mark, 1984, The Extraction of Drainage Networks from Digital Elevation Data, *Computer Vision, Graphics and Image Processing*, 28: 328-344.

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