AERIAL AND TERRESTRIAL LIDAR EQUIPMENTS FOR LAND MEASUREMENTS

ECHIPAMENTE AERIENE ŞI TERESTRE LIDAR PENTRU MĂSURAREA TERENULUI

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Abstract: *LIDAR is a relatively new technological tool (of optical teledetection) that can be used to accurately georeference terrain features; in some literature LIDAR (LIght Detecting And Ranging) is referred to as laser altimetry. A LIDAR system is composed of a laser scanning system, global positioning system (GPS), and an inertial measuring unit (IMU). We have aerial and terrestrial LIDAR.*

Rezumat: *LIDAR reprezinta un instrument relativ nou al tehnologiei (teledetectiei optice) care poate fi utilizat pentru o buna reprezentare georeferentiata a terenului; in unele carti LIDAR se refera la altimetria laser. Un sistem LIDAR este compus dintr-un sistem de scanare laser, dintr-un sistem global de pozitionare, precum si dintr-o unitate automata de masurare.*
Distingem LIDAR-ul aerian si LIDAR-ul terestru.

Keywords: *Digital Elevation Model, laser altimetry. Digital Terrain Model*
Cuvinte cheie: *Model Digital al Altitudinii, altimetria laser, Model Digital al Terenului*

INTRODUCTION

LIDAR is the acronym of **LI**ght **D**etection **A**nd **R**anging - a laser radar in light frequency range. LIDAR uses the concept of photons, while radar uses the concept of electromagnetic waves. LIDAR started in the pre-laser times in 1930s with searchlight beams, and then quickly evolved to modern lidars using nano-second laser pulses.

The first laser - a ruby laser was invented in 1960 by Schawlow and Townes [1958] and Maiman [1960] (construction). The first giant-pulse technique (Q-Switch) was invented by McClung and Hellwarth [1962]. The first laser studies of the atmosphere were undertaken by Fiocco and Smullin [1963] for upper region and by Ligda [1963] for troposphere. Following this, great strides were made both in the development of LIDAR technologies/systems, and in the sophistication of their applications. The first application of LIDAR was the detection of atmospheric aerosols and density. Basically, it is to know whether there are aerosols/density in the regions and how much. However, the composition of atmosphere cannot be told, because only the scattering intensity was detected but nothing about the spectra.

An important advance in LIDAR was the recognition that the spectra of the detected radiation contained highly specific information related to the species, which could be used to determine the composition of the object region.

MATERIAL AND METHODS

LIDAR actually started with altitude's determination. The invention of lasers pushed LIDAR to a whole new level - modern laser remote sensing. The time-of-flight of a short pulse is used to precisely determine range and altitude. Modern LIDARS have various formats and utilize different ways to determine altitude and range precisely.

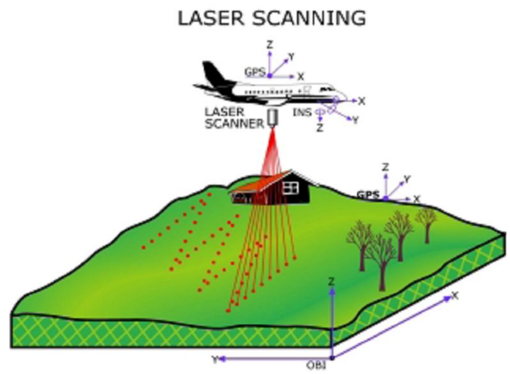


Figure 1 LIDAR system.

There are basically two kinds of lasers used in LIDAR [Ackermann, 1999]. These are the pulse lasers and the continuous wave (cw) lasers. Flood [2001] refers to these as small footprint, time-of-flight laser altimetry and large footprint waveform digitizing.

The pulse laser emits a narrow laser pulse in the near infrared region of the electromagnetic spectrum. Each discrete pulse is then reflected off a surface on the earth and returned to the receiver. This signal yields a small footprint on the surface of the earth. One of the problems with this method of LIDAR data collection is that acceptable results may be somewhat difficult to achieve in dense and complex canopies [Flood, 2001]. While the signal may penetrate to the ground through holes in the canopy, many returns have to be filtered for correct classification of the ground surface.

There are two distinct types of LIDAR systems based on the environment in which they are being used. A topographic system, which is the topic of this paper, is used over land and operates in the infrared portion of the electromagnetic spectrum. Over water, the infrared signal is partially absorbed by the water resulting in almost no return signal. A bathymetric system is used over water and it utilizes the blue-green portion of the electromagnetic spectrum, thereby allowing penetration and a return signal though the water.

While the speed of light is well known in a vacuum, one would expect that it would vary in the actual atmosphere. Thus, the raw distance, or sometimes called the range, is influenced by the variation in the actual speed of light. This variation can be modeled and corrected for in the processing of the raw laser signal.

In other classification, we accept two kind of LIDAR: aerial LIDAR and terrestrial LIDAR.

a. Aerial LIDAR is accepted as the most efficient and cost-effective means to create accurate digital elevation and terrain data. It has become the standard for flood mapping and many other applications requiring fast, accurate, inexpensive: Digital Terrain Models (DTMs); Digital Elevation Models (DEMs); other geospatial features;

Another use of LIDAR is that it helps in surveys for Pipelines and Exploration. Petroleum and utility companies need precise knowledge of the topography when planning the construction of pipelines, utility routes or the mapping of broad area exploration sites.

LIDAR is used for creating three dimensional topographical maps and surveys of geographical regions. LIDAR has been used in this way to create maps of Mars, to track glaciers or to visualize the Grand canyon.

LIDAR helps analyze the ocean floor and to determine canopy heights and biomass measurements. It also has applications in seismology and other geological features.

Our technology allows us to rapidly produce highly accurate cartographic and engineering products that usually present cost savings over traditional survey methods.

The laser beams are “between” 10 - 20 cm (4 – 8 inches) in diameter. Any portion of this beam area that strikes an object will trigger a reflection that will be measured by the scanner in terms of its geodetic position (it’s exact X, Y and Z co-ordinates).

This position is calculated from an onboard kinematic Global Positioning System (GPS) and ground based differential GPS stations that constantly receive information from a constellation of satellites.

What’s more, the scanner is also synchronized to an airborne digital camera that will determine the color of the object from which the reflection came (See Figure 2)

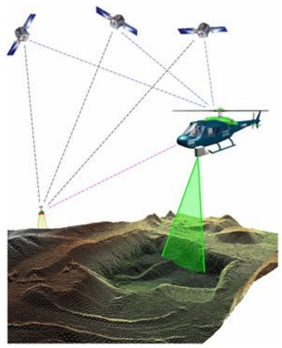


Figure 2: Aerial LIDAR

Advantages of airborne LIDAR

a. Speed; Airborne LIDAR acquisition and processing is incredibly fast. When the system is mounted on a helicopter, typically an area of 25m * > 750m will be captured every second. When operating from fixed wing aircraft, the area will be in excess of 50 m * 800 - 1500 m. The processing of LIDAR is rapid compared to other techniques used to generate 3D topographic models, such as photogrammetry.

b. High resolution; A LIDAR survey emits millions of infrared laser pulses for every route kilometer flown, capturing up to 40 points per square meter. This produces survey data of an unprecedented resolution, and even subtle changes in terrain are recorded. In the example below, (see Figure 3) a car is viewed in cross section. Surveys points have even been captured for the aerial!

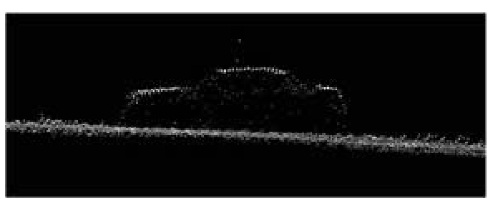


Figure 3: A car viewed in cross section if the surveys points have been captured for the aerial

c. Cost; In most cases aerial LIDAR will present large cost savings when compared to traditional survey methods.

d. Canopy Penetration; The laser beams penetrate the tree canopy, providing information on both the ground surface and any buildings or large objects. This means that we can produce models and maps of the ground even when they are masked by forest.

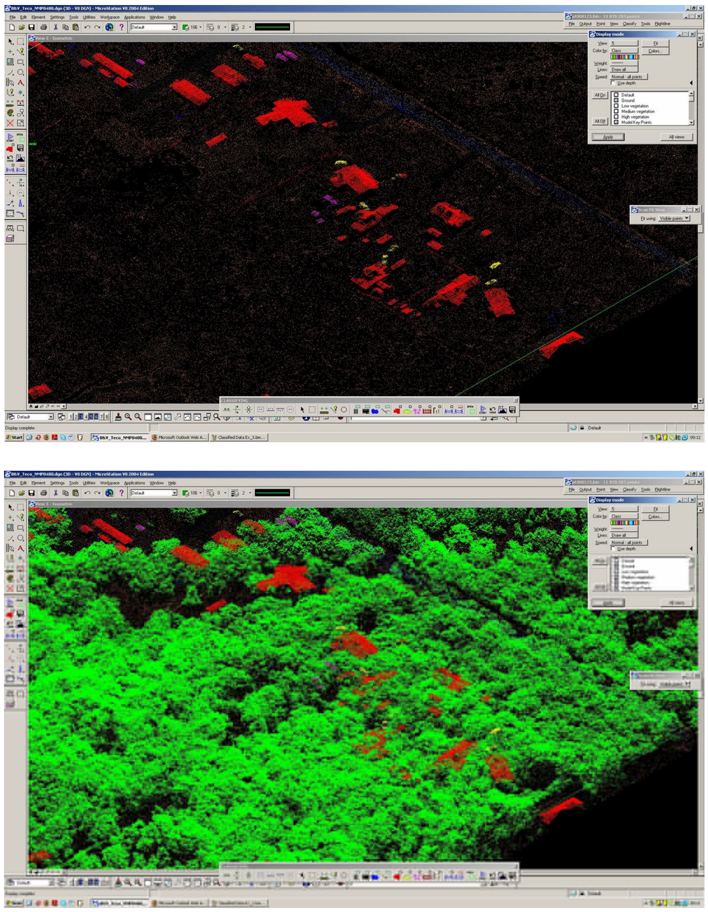


Figure 4: A forest area with buildings viewed with aerial LIDAR

e. Non-invasive; Airborne LIDAR enables surveys to be carried out in difficult and vast terrain, where ground survey is simply not feasible. LIDAR's surveyors are experts in mobilizing in inhospitable environments, (like the Ecuadorian rainforest and icecaps of Greenland, mountainous regions of Chilean Patagonia, the Alps and the Pyrenees).

f. Night-time Operation; Airborne LIDAR is an active remote sensing technique. LIDAR surveys can therefore be conducted during the night.

b. Terrestrial LIDAR

Terrestrial laser scanning is conducted from a ground based tripod and is used to generate an extremely accurate model of the ground in high resolution. It can also be used for above ground objects such as houses, transmission line towers and machinery.

All measurements are taken remotely, up to a range of 300 m, allowing the placement of equipment and personnel in non-hazardous areas.

Terrestrial laser scanning benefits mining. Laser scanner provides several advantages over conventional surveying methods for mining and transportation applications.

RESULTS AND DICUSSIONS

Standard outputs from LIDAR aerial surveys are:

1.Digital Terrain (DTM) Models; Raw 3D aerial LIDAR data can be processed using a range of techniques to produce accurate representations of the earth's surface, recording comprehensive coverage of topographic undulations. Unlike photogrammetry, aerial LIDAR survey is able penetrate the tree canopy. This means it is possible to produce a model of the ground surface below forested areas without interpolation. We are able to produce models of the ground surface in several different formats, including DTMs, TINs and contour models.

2.Point Cloud DTM; This is a raster DTM with each individual measurement recorded in its exact location.

3.Gridded DTM; This is a raster DTM of the ground surface with a set grid interval, such as 0.2 m spacing.

4.Triangulated Irregular Network (TIN) Models; A TIN is a vector-based representation of the ground surface where irregularly spaced nodes are connected by lines, creating a vast network of triangles. This is used to create a surface model from the 3D LIDAR point cloud, and to reduce the size of the data.

5.Contour Models; A contour model consists of lines representing nodes of equal height at set intervals. It is a way of representing a 3D surface in 2D. Aerial LIDAR data can be used for the rapid generation of accurate contour models, with intervals tailored to a client's requirements, ranging from metres to sub-decimetres.

6.Change Maps; The DTMs produced from two or more successive surveys can be compared to chart geomorphological movements over time. This includes erosion, aggradation, up-sidence and subsidence.

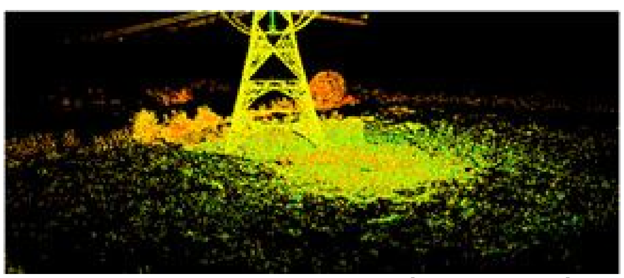
7.Digital Surface (DSM) Models; Digital surface models represent both the earth's ground surface and anything standing upon it. In the case of a forest, the DTM can be subtracted from the DSM to give a representation of timber volume.

8.Orthorectified Imagery; Can exist fully orthorectified imagery for the complete survey area. This is downward looking imagery that has been adjusted so that it has the geometric properties of a map.

9.Oblique Imagery; We can capture forward looking imagery of objects within the survey area. For example, we capture towers during electricity transmission line surveys as part of an integrated asset management system.

10.Vectorised Maps; We can provide 2 dimensional or 3 dimensional vectorisation of all features (such as hydrographic and transportation networks).

Applications of terrestrial LIDAR include small scale topographic survey, condition assessment, measurements of verticality and distortion, and as-built surveys.



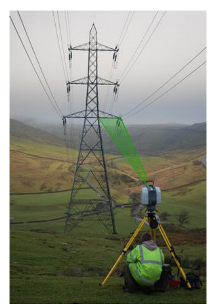


Figure 5: A topographic survey around a tower

With a combination of high resolution photography and laser scan data we are able to quantify the amount of (coverage and degree) on the tower (figure 6). This calculation is auditable against the XYZ intensity signatures.

From the as built surveys, we can take measurements of any steel sections. Corroded members can have exact replacements (figure 6).

Figure 6: LIDAR, as-built survey

The scanner records a 3D model of the structure, capturing the exact location and interaction of all components.

CONCLUSION

In two words, LIDAR technology utilizes the Global Positioning System (GPS), precision inertial navigation systems and high speed computing for data collection. LIDAR systems on airborne platforms (e.g., an airplane or helicopter) usually measure the distance between an object the laser beam hits and the airborne platform carrying the system. Airborne laser mapping instruments are active sensor systems, as opposed to passive imagery such as cameras. With LIDAR, it is possible to obtain elevation information on large tracts in relatively short time; elevation data obtained with LIDAR can be up to 6-inch accurate. LIDAR system uses the speed of light to determine distance by measuring the time it takes for a light pulse to reflect back from a target to a detector. A laser emitter can send about 5,000 pulses per second. Following a data collection flight, the data-tapes are transferred to a ground-based computer where a display of recorded data is immediately available. LIDAR systems produce data that can be used in digital elevation models (DEM). The high density of elevation points provides the possibility to create high-resolution DEM models. LIDAR has been effectively used in several applications including highway location and design and highway safety.

Airborne LIDAR technology is now a proven method for acquiring accurate digital terrain model data and associated imagery under a wide range of conditions. As an active sensor it can be used when other remote sensing tools will not work. But LIDAR technology is quite new and is difficult to master. Few companies around the world own the necessary equipment and even fewer offer data acquisition services that actually meet the needs of their clients.

We believe that access to a technology that enables the acquisition and fusion of baseline cartographic data and digital photos can speed up the initiation of projects related to road construction, mineral exploration, natural resources planning and exploitation, construction of infrastructure, environmental impact assessments and so on.

BIBLIOGRAPHY:

1. TURNER, A.K., 2000 - *LIDAR Provides Better Dem Data*. Applied Geoscience Forum
2. HUGHES, J., 2000 - *LIDAR Technology Reaches New Heights*. GEOWorld Journal, October
3. STONE, D., 1999 - *Country Reaps Rewards from Airborne Laser Survey*. CE News, November, pp. 58-60.
4. ACKERMANN, F., 1999 - *"Airborne Laser Scanning – Present Status and Future Expectations"*, ISPRS Journal of Photogrammetry and Remote Sensing, 54:64-67.
5. BRINKMAN, R. AND C. O'NEILL, 2000 - *"LIDAR and Photogrammetric Mapping"*, The Military Engineer, No. 605.
6. FOWLER, R., 2001 - *"The Thorny Problem of LIDAR Specifications"*, EOM, 10(4): 25-28.
7. MAUNE, D., editor, 2001 - *Digital Elevation Model Technologies and Applications: The DEM Users Manual*, American Society of Photogrammetry and Remote Sensing, Bethesda, MD.