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LiDAR Mapping: A Remote Sensing Technology

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Abstract: ***LiDAR stands for Light Detection And Ranging (or for Laser Imaging Detection And Ranging). It is an airborne optical remote-sensing technology which measures scattered light to find out range and other information on a distant target. This technology allows the direct measurement of three-dimensional structures and the underlying terrain. Depending on the methodology used to capture the data, the resultant data can be very dense. Lidar uses ultraviolet, visible, or near infrared light to capture object images. Also it can target a wide range of materials, including non-metallic objects, rocks, rain, chemical compounds, aerosols, clouds and even single molecules. A narrow laser-beam can map physical features with very high resolution.***

Keywords: LiDAR; RADAR; GPS; Laser; Photodetector

1. Introduction

LiDAR mapping is an active method of generating precise and directly georeferenced spatial information about the shape and surface characteristics of the Earth. [1] This method is similar to RADAR (Radio Detection and Ranging) technology, which uses radio waves; the range of an object is determined by measuring the time delay between transmission of a pulse and detection of a reflected signal. Instead of radio waves, LiDAR uses much more shorter wavelengths of the electromagnetic spectrum, typically in the ultraviolet, visible, or near infrared range.[2] This technology indicate that the speed, accuracy and information content that can be collected without impact to traffic or traditional survey safety concerns have the capacity to provide cost and schedule benefits. Recently, Light Detection and Ranging (LiDAR) based mobile mapping technology draws lot of practitioners' attention, and has been recognized as an efficient and economic method for gathering various types of roadway asset data. [3]

2. Components

A. Laser

600–1000 nm lasers are most common for non-scientific applications. They are inexpensive, but since they can be targeted and easily absorbed by the eye, the maximum power is limited by the need to make them eye-safe. Eye-safety is often a requirement for most applications. So, airborne topographic mapping LiDAR generally use 1064 nm diode pumped YAG lasers.[4]

B. Scanner And Optics

How fast images can be developed is also affected by the speed at which they are scanned. There are several methods to scan the azimuth and elevation, including dual oscillating plane mirrors, a combination with a polygon mirror, a dual axis scanner. Optic choices affect the angular resolution and range that can be detected. To collect a return signal, a hole mirror or a beam splitter are options.[4]

C. Photodetector and receiver electronics

Two main photodetector technologies are used in LiDAR: solid state photodetectors, such as silicon avalanche photodiodes, or photomultipliers. There is another parameter, sensitivity of the receiver which has to be balanced in a LiDAR design.[4]

D. Position and navigation systems

It requires instrumentation to determine the absolute position and orientation of the sensor that are mounted on mobile platforms such as airplanes or satellites. Such devices generally include a Global Positioning System (GPS) receiver and an Inertial Measurement Unit (IMU).[4]

3. Function

LiDAR is the integration of three technologies into a single system capable of acquiring data to produce accurate digital elevation models (DEMs). These technologies are; Lasers, the Global Positioning System (GPS), and Inertial Navigation Systems (INS). Combined, they allow the positioning of the footprint of a laser beam as it hits an object, to a high degree of accuracy. [5]

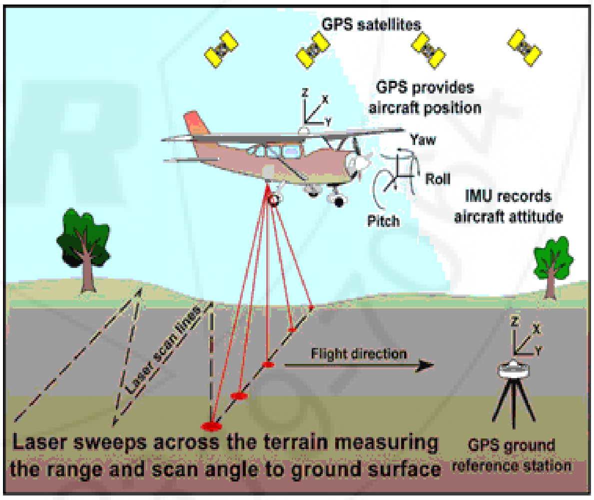

Figure 1: Airborne LiDAR System

LiDAR (Light Detection And Ranging)is popularly used as a technology to make high-resolution maps, with applications in geomatics, archaeology, geography, geology, geomorphology, seismology, forestry, remote sensing, atmospheric physics, airborne laser swath mapping (ALSM), laser altimetry, and contour mapping. [5]

a) How it works

- Ranging capabilities of lasers are very accurate, and also provide accurate distances to a few centimeters. But the accuracy limitations of LIDAR systems are due to the GPS and IMU (Inertial Measurement Unit) components.

- The LiDAR system unites a single narrow-beam laser with a receiver system. The laser produces an optical pulse that is transmitted, reflected off an object, and returned to the receiver. The receiver accurately measures the travel time of the pulse from its start to its return.[5]
- As the pulse travelling speed is same as the speed of light, the receiver senses the return pulse before the next pulse is sent out. Since the speed of light is known, the travel time can be converted to a range measurement.[5]
- By associating the laser range, laser scans angle, laser position from GPS, and laser orientation from INS, accurate x, y, z ground coordinates can be calculated for each laser pulse. Laser emission rates can be anywhere from a few pulses per second to tens of thousands of pulses per second. Thus, large volumes of points are collected.[5]

b)Lidar Platforms

- Airborne topographic LiDAR systems are the most common LiDAR systems used for generating digital elevation models for large areas. The combination of an airborne platform and a scanning LiDAR sensor is an effective and efficient technique for gathering elevation data across tens to thousands of square miles. For smaller areas, or where higher density is needed, LiDAR sensors can also be positioned on helicopters and ground-based (or water-based) stationary and mobile platforms.[1]
- LiDAR was first advanced as a fixed-position ground-based instrument for studies of atmospheric composition, structure, clouds, and aerosols and remains a powerful tool for climate observations around the world. NOAA and other research organizations operate these instruments to boost our understanding of climate change. LiDAR sensors are also mounted on fixed-position tripods and are used to scan specific targets such as bridges, buildings, and beaches. Tripod-based LiDAR systems generate point data with centimeter accuracy and are often used for localized terrain-mapping applications that require frequent surveys.[1]
- Modern navigation and positioning systems assist the use of water-based and land-based mobile platforms to collect LiDAR data. These systems are commonly built on sport-utility and all-terrain vehicles and may have sensor-to-target ranges greater than a kilometer. Data collected from these platforms are highly accurate and are used extensively to map discrete areas, including railroads, roadways, airports, buildings, utility corridors, harbors, and shorelines.[1]

4. Application

Table 1: LiDAR Applications

Sr. No.	*Application*	*Explanation*
1	Agriculture	This technology will help farmers improve their yields by directing their resources toward the high-yield sections of their land
2	Archaeology	For aiding in the planning of field campaigns, mapping features beneath forest canopy, and providing an overview of broad
3	Biology and conservation	In forestry. Canopy heights, biomass measurements, and leaf area can all be studied using airborne LiDAR systems
4	Geology and soil science	To detect subtle topographic features such as river terraces and river channel banks
5	Atmospheric Remote Sensing and Meteorology	Used to perform a range of measurements that include profiling clouds, measuring winds, studying aerosols and quantifying various atmospheric components
6	Military	The Airborne Laser Mine Detection System (ALMDS) for counter-mine warfare by Areté Associates
7	Physics and astronomy	To measure the distance to reflectors placed on the moon
8	Spaceflight	For range finding and orbital element calculation of relative velocity in proximity operations and station keeping of spacecraft. Also been used for atmospheric studies from space
9	Robotics	For the perception of the environment as well as object classification due to the ability to provide three-dimensional elevation maps of the terrain, high precision distance to the ground
10	Surveying	Airborne LiDAR sensors are used by companies in the remote sensing field
11	Wind farm optimization	To increase the energy output from wind farms by accurately measuring wind speeds and wind turbulence
12	Solar photovoltaic deployment optimization	Used to assist planners and developers optimize solar photovoltaic systems at the city level by determining appropriate roof tops and for determining shading losses

5. Advantages

- It has higher precision
- It is fast acquisition and processing technology
- It has least human dependence
- It has higher data density
- It has low cost

6. Disadvantages

- LiDAR may not penetrate to the ground surface in dense areas
- It is difficult to map plan features with high accuracy by using LiDAR

7. Conclusion

LiDAR is mapping tool which continuous to grow in application. It offers flexibility and it is environment friendly so because of that airborne LiDAR can be flown over areas where access is restricted, unachievable or unacceptable. Its flexibility and uniqueness to map medium and large areas cost effectively in terms of time, fidelity and detail has led to ever increasing demand for LiDAR.

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