Airborne Laser Survey Systems: Technology and Applications

Guangping HE

Lambda Tech International, Inc.
2323B Blue Mound RD., Waukesha, WI-53186, USA
Email: he@lambdatech.com

Abstract

As mapping products become increasingly digital and require rapid updating, it is necessary for survey companies to use fast and cost-effective technologies. Airborne laser mapping provides a new alternative for traditional photogrammetric mapping. Based on a scanning laser and GPS/Inertial positioning system, an airborne laser system automatically produces accurate digital elevation models (DEM) and digital images. Typical applications are mapping of forestry floors, determination of power line sags, monitoring of coastal zones, generation of urban models and surveying of the construction area. This paper will describe the system components, survey procedures and applications of airborne laser systems.

1 Introduction

Aerial photogrammetry is a traditional method for the survey of terrain surfaces. It makes use of overlapped aerial photographs to form stereo-models for measurement. However, it is difficult to obtain photographs of true ground surfaces in forest areas. Recently, airborne laser systems have been developed as an alternative to aerial photogrammetry.

An airborne laser survey system is built upon the integration of GPS, a precise inertial navigation system and a rugged high-speed laser scanner. It uses GPS and the inertial system (INS) to determine the position and orientation, and the high-speed laser to obtain distance to the ground by scanning the ground. Each distance measurement is then transferred into a three-dimensional ground surface point and the ground elevation model is then built.

Laser-based systems offer distinct advantages over aerial photogrammetry in some application areas. It uses laser to create the high density, high accuracy ground elevation model and eliminates the traditional stereo image requirement. It records the multiple laser returns and measures different elevation levels, e.g. tree tops and ground surface in forest areas. It takes images and ortho-rectifies them using laser generated DEM. Most importantly, the data processing is automated and very rapid.

In this paper, an overview of airborne laser survey systems is given in Section 2, system operation procedures in Section 3 and current applications in Section 4.

2 Airborne Laser Survey Systems: An overview

There are dozens of commercial companies who manufacture airborne laser survey systems or provide service [Ackermann 1996, Flood and Gutelius 1997]. Some examples of such systems include: the TopEys from Saab Survey in Sweden, ALTMS from Optech in Canada, Flip-Map from John E. Chance in the US, and Eagle Scan system and TopScan in Germany. Table 1 gives a brief comparison between TopEye, ALTMS and Eagle Scan systems. With all these companies competing, airborne laser systems have become affordable.

There are two steps to measurement procedure of airborne laser systems, i.e. (1) determining the position and rotation of the laser scanner and (2) locating a ground object using the laser measurement. In the first step, the GPS and INS data are integrated calculate three positional and three rotation parameters of the laser system. In the second step, the three-dimensional coordinates

Journal of Geospatial Engineering, Vol. 2, No. 2, pp. 51-55.

of a ground object are determined by laser distance and the three-dimensional coordinates are then transfered onto the global coordinate system.

Table1 A brief Comparison between the TopEye, ALTMS and Eagle Scan system

	Optech ALTMS, Optech	Saab TopEye	Eagle Scan
Price	$795,000	$1,500,000	Service only
Flight Medium	Fixed wing aircraft Helicopter	Helicopter	Fixed wing Aircraft
Laser pulse rate	2,000 per second	7,000 per second	4,000 per second
Scan angle	20 degrees	10 degrees	N/A
Eye safe range	300 meters	60 meters	300 meters
Horizontal Accuracy	from 1 meter	from 10 cm	from 1 meter
Swath width	240~750 meters	20~170 meters	150~900 meters

2.1 Positioning Module

The positioning system consists of GPS receivers and an inertial system (INS). The GPS provides accurate position data. Because of low data rates and the requirement of viewing at least four satellites, the use of GPS alone is limited. In contrast, the INS provides high rate position and attitude information, but its sensor errors tend to accumulate with time. By integrating GPS and INS, the accurate GPS position is used to calibrate the INS, and the INS then produces high rate, accurate position and attitude data, even when the GPS signals are lost [Gelb 1974]. The inertial system can also be used to stablize the laser system vertically.

2.2 Laser Ranger Finder

The laser ranger finder scans the ground with high rate laser pulses (e.g. 7000 pulse per second in the case of Saab TopEye) and records the distance from its center to the ground. Multiple laser echoes (e.g. up to five in TopEye) are recorded in each measurement. The pulsed laser beam moves across the flight direction as the system moves forward. This results in a Z-shaped measurement pattern on the ground. Point intervals on the ground are defined by the user by selecting the proper flight speed, height and laser scan rate.

2.3 Image Module

Most airborne survey systems have cameras mounted to take images of the survey area. In the TopEye system, one camera is mounted vertically with the field of view larger than scanning width. The second camera is mounted 45 degrees forward to record bird-view images. The position and orientation parameters are determined by the GPS and INS. With the DEM data created by the laser scanner, images can be automatically ortho-rectified and/or displayed in perspective.

3 Airborne Laser Survey Procedures

The data collection procedure of an airborne laser mapping system usually consists of mission planning, field data capture and post processing. Figure 1 illustrates the working procedure of the Saab TopEye system.

3.1 Mission Planning:

The purpose of mission planning is to prepare the survey procedure. The user needs to define the survey area, to select the flight routines, to set the system parameters and to check the GPS PDOP to make sure the accuracy requirements are met. In the Saab TopEye system, the mission planning software guides the user to determine the appropriate timing, the optimal survey routine and settings to meet the requirements. It also prepares a data set for real time navigation during data collection.

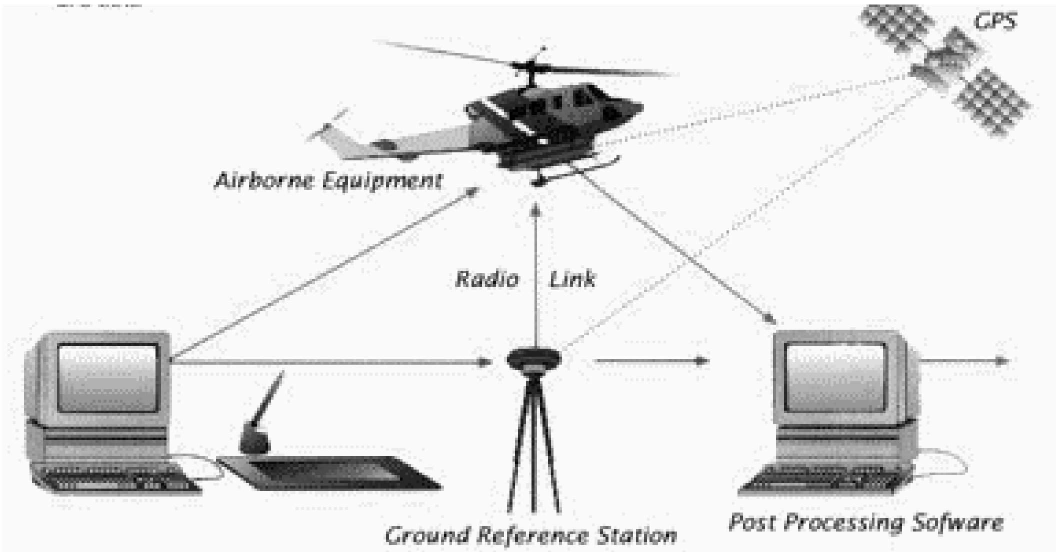

Figure1 The Saab TopEye Airborne laser mapping system working procedure

3.2 Field Data Capture

Most systems can be operated easily by one or two people. Controlling the system from a flight panel (that also includes guidance information), the pilot can optimize between a higher resolution or higher survey capacity. For most systems, all data including GPS, inertial system, laser measurements and images are recorded during the flight and will be processed after the flight. However, in some other systems, like TopEye, the GPS data is also processed in real time for navigational purposes.

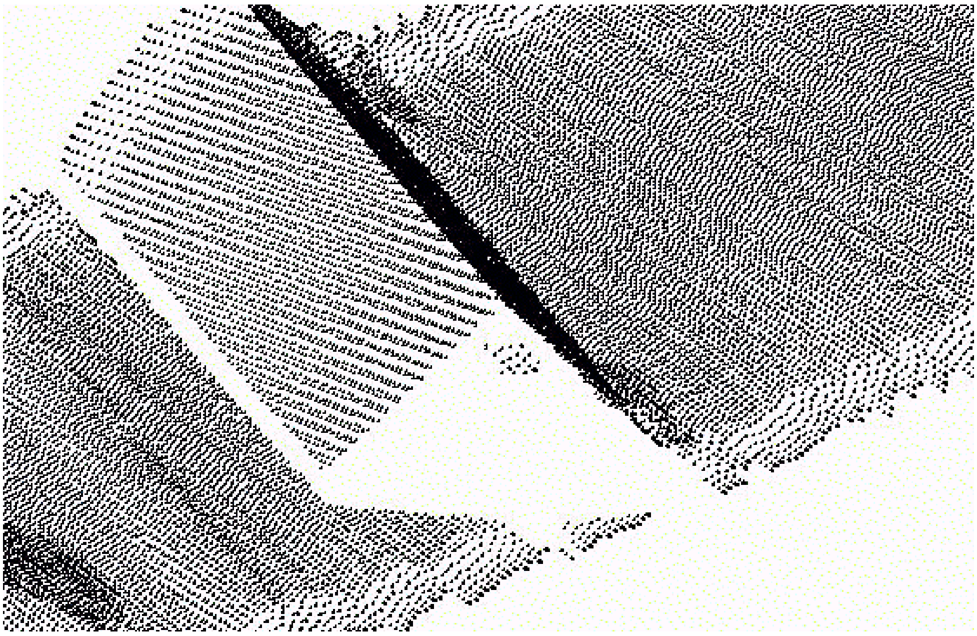

Figure 2 Raw individual ground points in perspective view.
(The data was collected in Arizona, USA with the Saab TopEye.)

3.3 Data Processing

During data processing, continuous positioning and orientation of the system is determined by integrating GPS and inertial data. The dual frequency GPS receiver provides accurate GPS points (e.g. 10cm) and the inertial system takes over positioning in between two GPS points. The positions of the three-dimensional ground surface are calculated from laser distance measurements with the known position and orientation of the system. Toints from Saab TopEye system are presented as X, Y, Z values together with time (t) and quality (q) (WGS-84 coordinate system) as a list and in a format suitable for further processing. Figure 2 illustrates the raw data of individual ground points collected with the Saab TopEye system and Figure 3 illustrates the same points but connected as lines according to the time sequence.

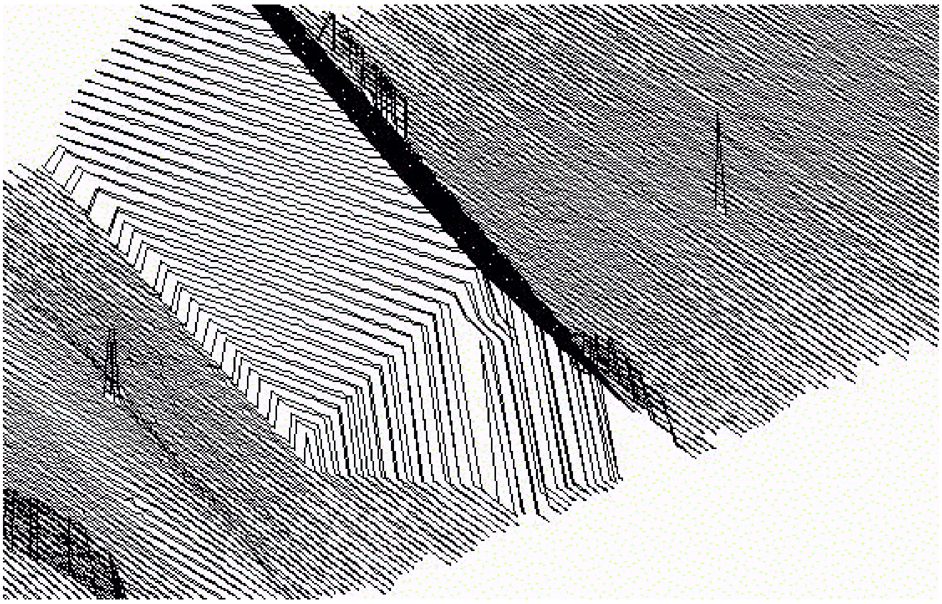

Figure 3 Data set in Figure 2 connected according to the time sequence

4 Applications

The airborne laser survey system is a new and emerging technology, competing with photogrammetry. Laser mapping systems have found wide applications in those areas where the traditional photogrammetry and field surveys are impractical or impossible impossible [Flood and Gutelius1997, Killian et al. 1996]. These applications includes:

a) **Power line surveys:** Traditional photogrammetry requires a large number of control points and has difficulty mapping the power line sags. Field surveys are too expensive or take too much time. The airborne laser system directly maps locations of points on both the power line and the ground. Separation between points on the ground and the power line are automatically performed (Figure 4).
b) **Coastlines surveys**: Coastline strips along the water edges are difficult to follow and is hard to map with traditional photogrammetry.
c) **Forest surveys**: The laser technique can measure the ground with the laser and can receive multiple laser returns. This enables the ground and tree tops to be measured at the same time. Such surveys are not possible with photogrammetry.
d) **Wetland and areas with mines**: In these area, control points are difficult to obtain. With the laser mapping system, the DEM is automatically generated, no control points are necessary except for the GPS base station. Figure 5 illustrates the DEM generated with the Saab TopEye system.
e) **Urban models**: It is difficult to measure building heights in a dense high building area with photogrammetry. However, it is easy with laser systems.

With its fast process time, its flexibility and no requirement for stereo image coverage, the airborne laser system has advantages over photogrammetry for such applications listed above. With new application software in development, its market share will increase in the future.

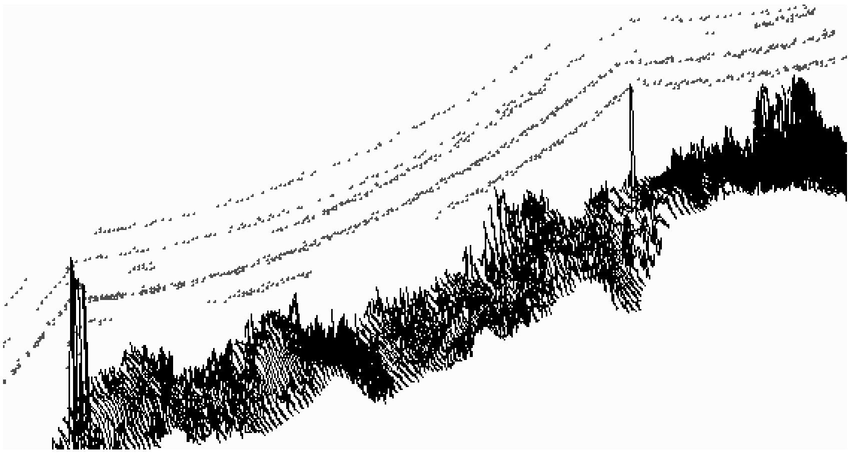

Figure 4. Power line sag detection and calculation using airborne laser mapping system

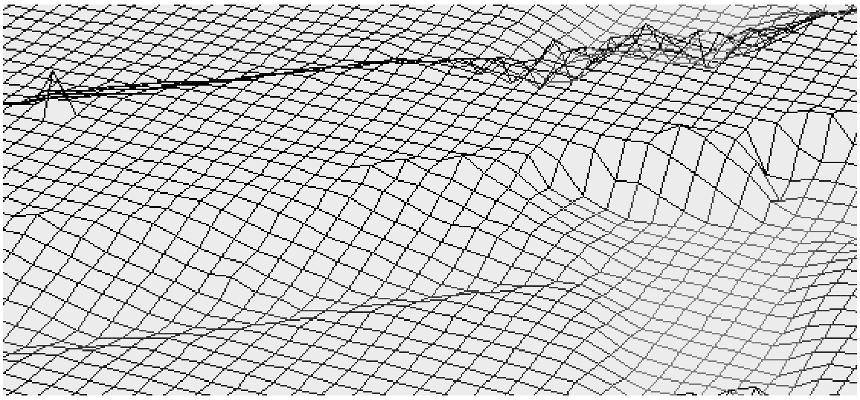

Figure 5. DTM generated with the Saab TopEye system

5 Concluding remarks

In this information age, the mapping world requires accurate digital information in a very short time frame. New and cost-effective technology is necessary for survey companies to compete. The airborne laser survey systems are being developed to meet this need. With rapid data processing, no need for control points and recording ability of multiple laser returns, airborne laser survey systems offer distinct advantages over the traditional photogrammetry in some applications such as survey of power line sag, coastlines, forests, mines fields and urban areas.

The airborne laser survey system is a new and emerging technology. The system themselves need to be improved and more application software needs to be developed.

References

Ackermann, F., 1996. Airborne laser Scanning for Elevation Models. *GIM* October Issue,

Flood, M., and Gutelius, B., 1997. Commercial Implications of Topographic Terrain Mapping Using Scanning Airborne laser Radar. *Photogrammetric Engineering & Remote Sensing*, Volume LXIII, Number 4, 327-329, 363-366.

Gelb A., 1974. *Applied Optical Estimation*. The MIT Press. Cambridge, Mass., USA

Killian, J., Halla, N., English, M., 1996. Capture and Evaluation of Airborne Laser Scanner Data. Int. Arch. of Photogrammetry and Remote sensing, Vol. XXXI, B3, Vienna, 1996, pp.385-388.

Saab Survey System, 1995. *Saab TopEye Instruction*. Saab Survey System ,Sweden.