Airborne Laser Scanning

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THE AUTHORS

David Turton has been involved with mapping and other applications of photogrammetry for 35 years - 30 of these with AAM Surveys. He has been investigating Airborne Laser Scanner technology for a number of years and is the principal force within AAM in its introduction to Australia. Dave is a director of AAM and operates from the Brisbane office.

Ian Powell has had a long career in the surveying industry both in the private sector and in government. Since our last Conference, Ian has left his position as Manager Waste & Land Information at the Environment Protection Authority and has joined AAM Surveys in their Sydney office.

INTRODUCTION

AAM Surveys was established in 1959 as Australian Aerial Mapping with the aim of making photogrammetry an everyday surveying procedure in Australia. The company has been at the forefront in introducing further technological improvements over the intervening years. In 1992, AAM introduced "Sky Control" to its aerial photography operations. "Sky Control" provides precise aircraft positions at the time of exposure of each photograph using kinematic differential GPS measurements. As well as making the aerial photography operation more efficient, aerial triangulation is now more accurate.

To ensure that the company remains at the technological leading edge, an extensive series of experiments were conducted in 1998 to test Airborne Laser Scanning (ALS) under Australian conditions. This paper describes the principles of this technology and gives some practical examples of how it has been used in Australia.

BACKGROUND

In the 1960's, the Australian National Mapping organisation introduced radar profiling as a means of improving vertical control for its 1:100,000 standard mapping program. The location of the aircraft was controlled with a radio frequency ranging system called Aerodist. The Defence Research Establishment in Salisbury, South Australia progressed the technology and produced a hydrographic application using red and green lasers in their profiler to determine depths of water.

Airborne laser scanning has developed from these earlier laser profiling systems. In 1988 work started on production of an airborne measuring system, which could gather a dense ground and non-ground data set over a wide swathe of country. This contrasts with the profilers, which gathered data only immediately beneath the aircraft. Software to post process the large amounts of data gathered was developed in Germany and in 1993 the first scanning laser was delivered which utilized an Optech scanning laser together with Topscan processing software. Research in Canada and Europe, adding the scanning dimension to airborne laser ranging has thus opened the door to an effective method of quickly capturing a digital elevation model of the terrain.

THEORY

The Airborne Laser Scanner consists of a laser emitting a continuous stream of light, which passes through a rotating mirror. The resultant light "pulses" are transmitted to the ground, perpendicular to the direction of flight, in a series of "scans". The pulses can be varied from 65 to 10,000 Hz. Up to thirty scans per second are possible resulting in a saw tooth pattern of data across the swathe being measured. The flying height and the speed of the aircraft can also be varied so that a suitable sampling intensity can be designed. The distance between points ranges from two metres to sixteen metres.

The position of the aircraft is determined using differential GPS whilst the variation in aircraft heading, tip and tilt are recorded, to an accuracy of approximately 0.04 degrees of arc, by an inertial system in which the laser scanner is mounted. The time taken for each discrete laser scan pulse to travel to and return from a point within the swathe is accurately measured.

Post processing of data utilises GPS, inertial and pulse travel time to calculate x y and z coordinates with a 15cm height accuracy. Accuracies are predominantly dependent on measurement of the aircraft tips, tilts and heading. These errors have a large effect at the edges of the swathe where the distance from the aircraft flight line is maximised. GPS location and pulse travel times are independent of flying height. The nature of the reflective surface and the size of the laser beam where it strikes the ground may also affect the vertical accuracy.

Sophisticated filtering algorithms then separate ground and non-ground laser strike points to produce separate digital elevation models for each surface.

ADVANTAGES OF AIRBORNE LASER SCANNING

- Like other remote sensing technologies, ALS provides a rapid means of gathering ground data – in this instance, the three dimensional location of an array of points below the aircraft flight line.
- Photogrammetry also can produce accurate three dimensional data but may be restricted by lack of light or excess reflectance such as occurs over sand, snow or ice. Because ALS is an active remote sensing system, it can theoretically be used day or night, in clear or overcast weather.
- ALS has the ability to penetrate tree canopies and obtain direct ground measurements.
- Site occupation is not required; and
- Spatial data can be obtained in inaccessible areas.

DISADVANTAGES OF AIRBORNE LASER SCANNING

- No pictorial record is obtained directly by the instrument. Separate camera or video images may need to be obtained at the same time.
- For best results, it is advisable to install a GPS base station within 50 kilometres of the site being sampled.
- The large volumes of data generated by this system requires special handling procedures.

OVERSEAS EXPERIENCE

The above advantages have been put to good effect in projects overseas. For example, the National Research Council of Canada (Magnussen & Boudewyn) has reported the use of ALS for determination of the distribution of canopy heights of Douglas Fir. The result of their comparison of ALS and field data explained why estimation of stand heights from laser scanning data have been successful in practice.

ALS is being used (Favey & Geiger) to determine changes in glacier thickness on the Unteraar Glacier, Switzerland. Two sets of laser scanning measurements were successfully taken in 1997 and 1998, the first one serving as reference for later temporal changes of the glacier surface.

In the USA, the National Oceanic and Atmospheric Administration have used Airborne Laser technology in the assessment of coastal erosion.

In Germany, ALS has been used in establishing building footprints, locations and densities (Kilian, Haala & Englich, 1996). Tests were also performed in 1998 to determine the accuracies and economics of using ALS in creating part of the country-wide DTM to support the production and updating of the existing 1:5,000 base map series.

In The Netherlands, our associate company (Geodan Geodesie bv) has been involved (amongst many other projects) in the digital elevation mapping of coastal areas for two dune water utility companies.

Common to all these projects, is the need to obtain precise aircraft positioning with differential kinematic GPS.

AUSTRALIAN EXAMPLES

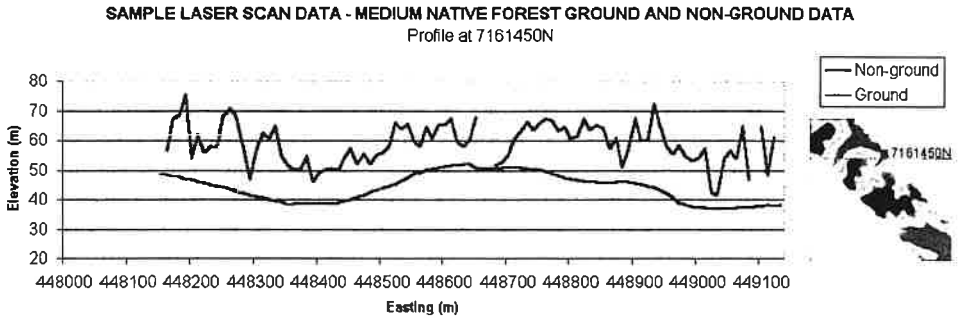
Airborne Laser Scanning is ideally suited to providing elevation data over inaccessible terrain, particularly terrain that is tree covered or where ground survey is dangerous or time consuming. Well over 20 projects were completed by AAM last year, with the following three applications giving some indication of ALS capabilities.

Forest Survey at St. Marys near Maryborough, Qld.

This site was chosen in order to demonstrate the ability of ALS to reliably record the ground beneath trees as well as the tree canopy. The site consists of medium eucalypt forest with bushy re-growth and grassy clumps. Ground surveys in this type of area would be labourious and expensive. Photogrammetric operators would have difficulty in penetrating the forest cover to obtain a sufficient number of ground elevation values.

Ground survey data was obtained over test areas and compared with ALS data. A resulting standard deviation of 0.13m was calculated.

A section through the data clearly shows the separate ground and tree canopy data.



A similar ALS survey was measured in a dense plantation of 50 year old hoop pine. No ground surface was visible at all in the aerial photography yet the ALS was able to obtain a suitable number of ground measurements. Part of this plantation has since been cleared, allowing direct field measurements that have indicated a standard deviation of ALS height data to be 0.8 metres. The reduced accuracy is put down to the presence of litter and low vegetation under the trees plus the steepness of the ground which could introduce a 0.5 metre error over the 1 metre wide area illuminated by the laser.

Sand Dune measurements at Wedge Island, W.A.

The Wedge Island project demonstrates the ability of ALS to produce a DTM of the inter-tidal zone and also to penetrate vegetation growing on the sand dunes sufficiently to allow ground contours and profiles to be generated. Normal ground survey methods could not complete the survey within the time that the tide was out. Photogrammetric operators using high magnifications would have difficulty in getting a clear stereoscopic image because of the glare and the lack of tonal variability.

Field surveyed data was collected over the dune area and comparison with ALS data produced a standard deviation of 0.20m.

Power Line Survey in Central Queensland

Highly detailed and complex information can be recorded with ALS. With power line surveys, airborne laser scanning can be used to produce a profile of the ground, vegetation and power lines from which vegetation growing in close proximity to power lines can be identified. Such vegetation has been a major hazard in the past and is thought to have been the cause of major bushfires in Victoria and elsewhere. A large quantity of data must be recorded to define individual power lines. Surveys of this type can be undertaken with a fixed wing aircraft or with a helicopter. At the same time, the temperature of the wires can be remotely sensed and the wind speeds across the line measured. From this data, the catenary of the power lines can be measured and the strain on the cables determined. In the following illustration, the vegetation is clearly seen to be growing up to the power lines.

Power line long section showing tower, cables, vegetation and ground.

CONCLUSIONS

- Trials have clearly shown that Airborne Laser Scanning technology can be used to provide reliable Digital Terrain Model and Digital Elevation Model (not necessarily of the terrain surface) data.
- A statistical analysis of our ALS results is currently being peer reviewed. A paper setting out these results will then be prepared.
- The ability to penetrate vegetation and record the ground beneath allows spatial data to be gathered economically where before only laborious field surveys could be used.
- Since site access is not required, surveys can be undertaken of mudflats and other inter tidal areas where ground access is difficult, expensive or dangerous.
- AAM's trials in 1998 have demonstrated the practicality of Airborne Laser Scanning in the Australian context. Accordingly, the company has now set up a joint venture company called AAM Geodan to provide this service on a continuous basis throughout Australasia and countries of the Pacific Rim.