

Production of ALS and RGB/CIR true ortho images

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Airborne Laser Scanner Systems (ALS) are well known since years. Most of them use a kind of rotating or oscillating mirror as a mean for beam deflection. This paper presents a much more reliable and accurate concept of laser beam deflection and shows case studies of projects of so called high precision laser scanning



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TO CALCULATE an elevation model from data acquired by an airborne laser scanner (ALS or Lidar) one needs to know four basic parameters (Figure 1):

- Distance from the sensor to the ground/object
- Sensor position
- Sensor orientation (attitude)
- Beam deflection

But knowing these parameters as good as possible will not automatically lead to a perfect elevation model. Due to the nature of the measurement principles, an airborne Lidar measurement is always a measurement from a random reflector which can not be repeated. So, an individual measurement is not reliable and highly reliable elevation models can only be achieved by processing a lot of adjacent measurements.

The basic components of an ALS are depicted in Figure 2. Essentially they are completely independent elements which need to become a system by integrating them mechanically, optically and electronically. Only if this is done very precisely, one can expect an ALS working properly.

The following section gives an outline about these components with a special focus on beam deflection.

DISTANCE MEASUREMENT

The distance is measured by counting the time duration between the emission of the laser pulse and the reception of the echo (or reflection from ground or objects) and by converting this 'time of flight' (TOF) of the laser pulse into distance.

Echo detection means first to recognize the reflected laser light and then to register the echo. The most common approach is to take the raising edge of the echo as reference, because this edge of a laser pulse is usually much steeper than the trailing edge. Applying a threshold means that weak echoes cause a longer distance measured than strong echoes. A similar effect results from a slant viewing to the ground which causes a longer rise time of the echo and thus a delayed stop of the counter. TopoSys uses an adaptive threshold and thus measures always the same distance independent from the amplitude of the echo.

TopoSys applies a laser operating at a wavelength of 1.56 μm . Light at this wavelength gets reflected completely from water-surfaces and thus the TopoSys system provides reliable distance measurements over water. Light at shorter wavelengths penetrates partially into the water leading to a reflection from within the water and to a longer rise time of the echo.

SENSOR POSITION AND ORIENTATION

Almost all high-end ALS systems use differential GPS to acquire the sensor position. The typical accuracy one can achieve is in the range of 0.05m to 0.1m if one takes into account some restrictions like GPS quality and distance to the ground station.

Attitude is mostly derived by the use of an IMU which measures accelerations and angular rates from which velocity, position and attitude are calculated by integration. To correct drifts, IMU and DGPS position are combined to achieve a very precise attitude and position data of the IMU.

One very essential matter is that the IMU has to be aligned precisely to the earth's center of gravity. If there is even a minor miss-alignment this will result in tilts of the survey strip. The alignment can be done on ground prior to take-off or by in-flight alignment if the appropriate software is in use and if spe-

cific flight maneuvers are applied. If pilots are properly instructed, these maneuvers form part of the survey flight and do not require additional flight time.

LASER BEAM DEFLECTION

IMU and GPS provide position and attitude of the sensor, but not the orientation of the laser beam. This is influenced by the device deflecting the laser beam perpendicular to the flight direction. The concept which is used to move the beam has got a great influence on the quality of the sensor system and the quality of the products as well as on mission restrictions and sensor efficiency. Currently three concepts are used:

Oscillating mirror

The beam is deflected by an oscillating mirror (Figure 3). Basic advantages are a quite flexible adjustment of the required viewing angle. Basic disadvantages are:

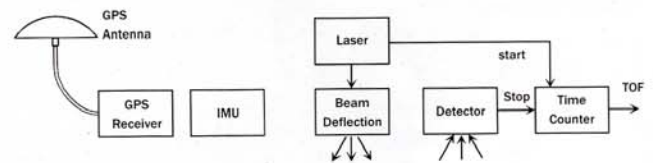
- Additional error due to the mechanics, accelerations and wear-out
- Inhomogeneous scan pattern on ground
- Strong reciprocal relation between viewing angle and scan frequency
- Regular calibration required

This makes this concept not suitable for high precision Laser scanning but quite useful for small scale mapping. This concept is used by e.g. Optech and Leica.

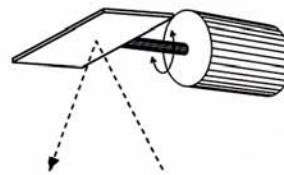
Rotating mirror

The beam is deflected by an rotating polygon mirror (Figure 4). Basic advantages are a flexible adjustment of the required viewing angle. Basic disadvantages are:

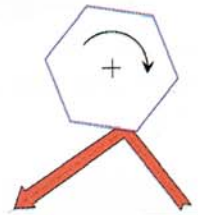
- Additional error due to misalignment of the surfaces of the mirror and wear-out
- Inhomogeneous scan pattern on ground at wide scan angles
- No practical use of the theoretically possible wide scan angle due to loss of measurements at the border of the scan
- Regular calibration required



▲ Fig 2 Basic Components



▲ Fig 3 Oscillating mirror



▲ Fig 4 Rotating mirror

This makes this concept also not suitable for high precision Laser scanning but quite useful for small scale mapping or for terrestrial scanners. This concept is used by e.g. Terrapoint or Riegl.

Fiber Scanner

The beam is deflected by fixed linear array of fibers (Figure 5). Basic advantages are:

- Laser pulse rate is not linked to the viewing angle and flight height
- Dense and regular scan pattern
- No calibration required after factory setting
- Embedded push-broom RGB/NIR scanner

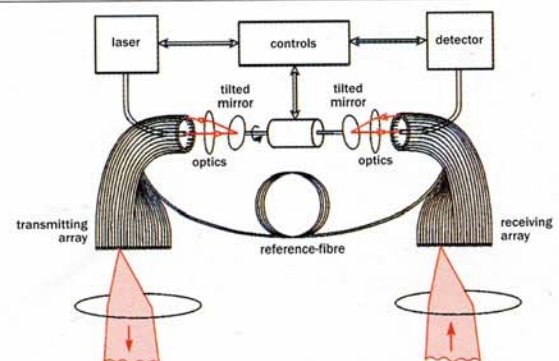
Basic disadvantages is the fixed viewing angle. This concept is perfectly suitable for high precision Laser scanning and only used by TopoSys.

The light guiding fibers are arranged at one end in a circle and at the other end in a fixed linear array. The laser pulse is coupled from the laser into one of the fibers arranged in a cir-

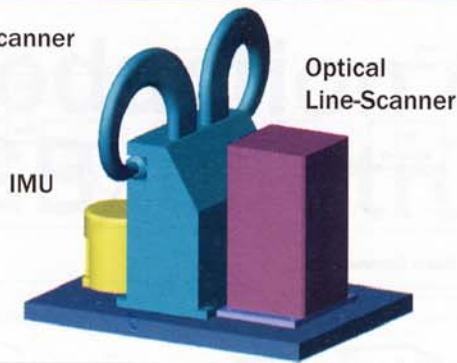
▼ Fig 1 General Principle Of Airborne Laser Scanning (ALS)



▼ Fig 5 Fiber based ALS system



Fiber-Scanner



▲ Fig 6 Mounting of IMU and Fiber Scanner

cle at the left side of the diagram. From there it formed to a narrow beam and transmitted to ground. The reflected light is focused to the corresponding fiber at the receiving side from where it is guided to the circular array and coupled into the center fiber leading to the detector. The direction of a transmitted laser beam is given by each individual fiber and remains stable. Any miss-alignment within this arrangement will lead to a loss of energy but not to a false direction.

REFERENCE FIBER

Counting the time of flight is influenced by all the various electronic devices from the electro-optic receiver to the time counter. Its accuracy might therefore degrade with temperature and/or aging processes. One of the fibers is directly fed from the transmitting side to the receiving side (Figure 5). This 'reference fiber' has a precisely calibrated optical length of 2,200 m, simulating a distance of 1,100 m. The signal is attenuated such that it corresponds to an echo from a low reflecting surface. This distance is measured once per scan (i.e. each 1.6 msec) and is used to monitor all ranging electronics and eventually to correct for degradations.

BORE-SIGHT ALIGNMENT

The fiber scanner guarantees a precise knowledge about the

▼ Fig 7 1m surface model of river Elbe, havel and Mittelland canal



▲ Fig 8 Falcon II mounted in a Piper Seneca

beam direction with respect to the fiber-scanner itself, but not necessarily with respect to the orientation of the sensor or the IMU. For this fiber-scanner and IMU are mounted close together on a CFRP plate as shown in Figure 6. This ensures that the orientation between both becomes invariable against any mechanical forces induced by the aircraft or forced by thermal variations.

The bore-sight alignment for both is established by at least one specific calibration flight taking a large set of buildings of which the coordinates of the roof have been measured conventionally to a cm accuracy. To reduce the influence of errors from the DGPS positioning, such a calibration flight is done only at favorite conditions.

CASE STUDY

TopoSys operates the Falcon (Figure 8) since 1996 in aircrafts and helicopters and has acquired ten thousand of square kilometres of high resolution and high accurate elevation models and RGB/CIR true-ortho images.

Typical products are DSM and DTM models of resolution from 2 metre to 0.5 metre and RGB/CIR true-ortho images of resolutions from 1 metre to 0.25 metre.

The image (Figure 7) shows a area in Germany. It is a colored image derived from the 1m digital surface model. The elevation data have been acquired in 2002 for a large hydrographic project covering more than 1,000 sq km.

The small area in the image shows the crossing of the 'Mittelland' canal over the river Elbe including the two locks connecting the canal, the rivers Elbe and Havel all three being navigable.

CONCLUSION

The basic principles of airborne Lidar scanning and the main parts of a airborne Laser scanning system have been presented. The major components have been discussed briefly. Current ALS can be classified by their concept they use for beam deflection. Three methods have been shown and discussed with a special focus on high precision laser scanning. ■