University Of Technology
Building and Construction Eng. Dept.
Final Exam/ First Attempt –2014/2015

Subject :Laser Scanning   Class: 3 rd Year
Division : Geomatics   Time : 3.0 Hour
Examiner :Dr. Imzahim Abdulkareem   Date: Monday 8/6/2015

Note: Answer All Questions

Q1) [20 marks] **(Answer Two items Only)**

A. A laser Scanning spaceborne operating at altitude 2500 m with speed 75 m/sec, the pulse duration of the scanning system is 10 ns and the peak power is 15 kW, which emits its pulses with a pulse repetition rate of 83 kHz, and the very high scan rate of 630 Hz at the wavelength (λ) of 1540 nm. If you know the scan angle is 30°, compute the following: 1) The minimum resolvable distance between targets 2) Maximum slant range. 3) Swath width. 4) Point spacing in both direction, if you know the scan rate up to 50,000 point/ line. 5) Point density. 6) Overlapping factor, if you the flight line separation is 400 m.

Solution:

$$\omega = 2.44 \times \frac{1540 \times 10^{-9}}{4.807 \times 10^{-4}} = 7.817\, mrad$$

$$\text{d (diameter of Footprint)} = R \times \omega$$

$$d = 2500\, m \times \left(\frac{7.817}{1000}\right) = 19.542\, meters$$

$$A = \pi d^2/4 = 300\, m^2$$

$$\Delta R_{tar} = \frac{c}{2} . T_p = \frac{3 \times 10^8}{2} .10 \times 10^{-9} = 1.5\, m$$

$$R_{max} = H/cos\left(\frac{\theta}{2}\right) = 2500\, m \times cos^{-1}\left(\frac{30^\circ}{2}\right) = 2588.190\, m$$

$$SW = 2 \times H \times \tan\left(\frac{\theta}{2}\right) = 2 \times 2500 \times \tan\left(\frac{30}{2}\right) = 1339.75\, m$$

$$\Delta x_{along} = \frac{v}{f_{sc}} = \frac{75\, m/sec}{630\, Hz} = 0.119 m$$

$$\Delta x_{across} = \frac{\theta}{N} . \frac{H}{cos^2(\frac{\theta}{2})} = \frac{(30 \times \pi/_{180})}{50000} \times \frac{2500\, m}{\cos\left(\frac{30}{2}\right)^2} = 0.028\, m$$

$$d_{min} = \frac{1}{\Delta x_{along} . \Delta x_{across}} = \frac{1}{0.119 \times 0.028} = 300.12\, Points/m^2$$

$$\xi = 1 - \frac{e}{SW} = 1 - \frac{400\, m}{1339.75\, m} = 0.7014$$

B. LiDAR CW signals using a 1 GHz ranging signal, which corresponds to a wavelength λ of 30 cm, and assuming a phase resolution of 0.4°, calculate the range resolution? And the unambiguous range?

$$\Delta R = \frac{\lambda}{4\pi} \cdot \Delta\emptyset = \frac{\left(30\ cm \times \frac{10mm}{cm}\right) \times (0.4^{\circ} \times \frac{\pi}{180})}{4 \times \pi} = 0.166m \approx 0.2\ mm$$

$$R_{Unamb} = \frac{\lambda}{2} = \frac{300\ mm}{2} \approx 150\ mm$$

C. Summarize and sketch draw for Topographic LiDAR systems consist?

Solution:

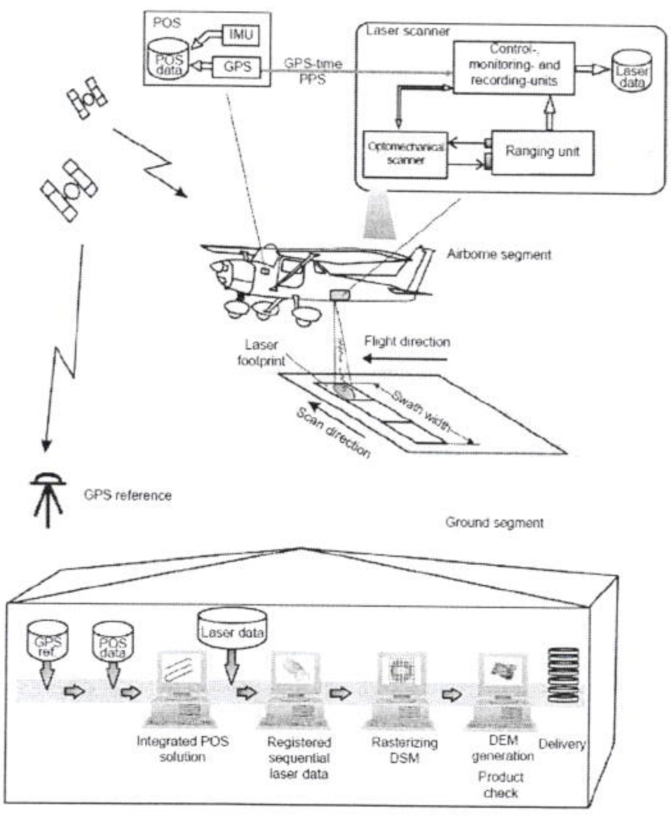
The Topographic LiDAR systems used to execute the survey activities, because a valid surveying result is impossible if a LiDAR is used as an isolated device. A surveying result means geocoded laser measurements. Figure 2.1 shows that LiDAR systems consist of an airborne and ground segment.

The airborne segment includes:

1) Airborne platform
2) LiDAR
3) Position and orientation system (POS)

The ground segment is comprised of

1) Global positioning system (GPS) reference stations
2) Processing hardware and software for synchronization and registration which is carried out off-line



Q2) [20 marks]

A Laser Scanning Airborne flying at altitude 2500 m ; if you know the XYZ geocentric coordinates for LiDAR data system through POS unit is X=820,600.00 m , Y=-5,800,750.656, Z=3,140,700.300 m . The Longitude of the local origin $\lambda_0 = 85^\circ 45' 0'' West$ and the Latitude of the local vertical origin $\phi_0 = 28^\circ 46' 10'' North$

Use ellipsoid parameter for GRS80 [a=6,378,137m, f=1/298.25722210088]

1. Convert LiDAR data geocentric coordinates to local vertical coordinates $X_L, Y_L \ and \ Z_L$?
2. Convert back to the original geocentric coordinates?

Solution:

1.

$$e^2 = f\,(2-f) = \frac{a^2 - b^2}{a^2} = 0.006694380023$$

$$N = \frac{a}{\sqrt{1 - e^2 sin^2 \emptyset}} = 6383400.249\ m$$

$$x = (N + h)\cos\emptyset\cos\lambda = 811195.778\ m$$

$$y = (N + h)\cos\emptyset\sin\lambda = -5482371.413m$$

$$z = [N(1 - e^2) + h]\sin\phi = 3146343.779\ m$$

$$\begin{bmatrix} x_l \\ y_l \\ z_l \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix} \begin{bmatrix} x - x_0 \\ y - y_0 \\ z - z_0 \end{bmatrix}$$

$$M = \begin{bmatrix} 0.98922979728 & 0.14637079003 & 0 \\ -0.072631601671 & 0.49087215134 & 0.86819881449 \\ 0.12707894638 & -0.85884813725 & 0.49621650368 \end{bmatrix}$$

$$\begin{bmatrix} x - x_0 \\ y - y_0 \\ z - z_0 \end{bmatrix} = \begin{bmatrix} 815519.912 - 811195.778 \\ -5482723.662 - (-5482371.413) \\ 3144707.279 - 3146343.779 \end{bmatrix} = \begin{bmatrix} 4226.003 \\ -1907.785 \\ 39.976 \end{bmatrix}$$

3. Convert back to the original geocentric coordinates

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = [M^T] \begin{bmatrix} x_l \\ y_l \\ z_l \end{bmatrix} + \begin{bmatrix} x_0 \\ y_0 \\ z_0 \end{bmatrix}$$

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = [M^T] \begin{bmatrix} 4226.003 \\ -1907.785 \\ 39.976 \end{bmatrix} + \begin{bmatrix} 811195.778 \\ -5482371.413 \\ 3146343.779 \end{bmatrix} = \begin{bmatrix} 815519.912 \\ -5482723.662 \\ 3144707.279 \end{bmatrix}$$

Q3) [30 marks] **(Answer Two items Only)**

A. Define the following terms: [15 marks]

Direct detection laser receivers, heterodyne receivers, Airborne Laser Profilers, Registration

Direct detection laser receivers: are convert the echo directly into a voltage or current using PIN (**Positive, Intrinsic, Negative**) or APD (**Avalanche photodiodes**).

Heterodyne receivers: down-convert the received signal to a lower frequency by mixing with the output of a stable local oscillator. The signal can then be amplified and filtered to enhance the detection process.

Airborne Laser Profilers: The first lasers had been constructed and demonstrated, they began to be used for rangefinding purposes.

This device could measure flying heights of 1000 ft. (300 m) above ground level (AGL) to an accuracy of 5 ft. (1.5 m). Shortly after that, the first airborne laser profiler was introduced for use in commercial topographic mapping operations.

The rangefinder part of the system was based on a helium-neon gas laser operating as a continuous wave (CW) device at the wavelength of 632.8 nm. The output signal was modulated using a KDP crystal that allowed the radiation to be emitted simultaneously at three different frequencies −1, 5, and 25 MHz

In each case, the return signals reflected from the ground were received and compared with the transmitted reference signal to determine the respective phase differences, so determining the actual range.

Registration: The registration process is best mathematically described by the simple vector approach already $\vec{G} = \vec{r_L} + \vec{s}$ $\vec{G}$ is the vector from the earth center to the ground point where: $\vec{r_L}$ vector from the earth center to the LiDAR's point of origin $\vec{s}$ slant ranging vector

B. Compute the terrestrial laser ranger, different in the height and resolution of a single measured range, if the measurement of the terrain profile is executed in a series of steps with the successive measured distances (slant ranges) and vertical angles equal $9^\circ 00' 00''$ while the value of the horizontal distance is 750 m; if you know the timing of the pulse is equal to 3 ps (picoseconds). [15 marks]

$$D = R\cos V$$

$$R = \frac{D}{\cos V} = \frac{750\ m}{\cos 9^\circ 00'00''} = 759.3488\ \ m$$

$$\Delta H = R\sin V$$

$$\Delta H = 759.3488\ \times \sin 9^\circ 00'00'' = 118.788\ m$$

f = PRF=1/t = 1/(3 × 10^{-12}) sec.

C= 300,000,000 m/sec