GENERATION OF AIRBORNE LIDAR INTENSITY IMAGE BY NORMALIZAING RANGE DIFFERENCES

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ABSTRACT : Airborn Lidar technology has been applied to diverse applications with the advantages of accurate 3D information. Further, Lidar intensity, backscattered signal power, can provid us additional information regarding target's characteristics. Lidar intensity varies by the target reflectance , moisture condition, range, and viewing geometry. This study purposes to generate normalized airborne LiDAR intensity image considering those influential factors such as reflectance, range and geometric/topographic factors (scan angle, ground height, aspect, slope, local incidence angle: LIA). Laser points from one flight line were extracted to simplify the geometric conditions. Laser intensities of sample plots, selected by using a set of reference data and ground survey, werethen statistically analyzed with independent variables. Target reflectance, range between sensor and target, and surface slope were main factors to influence the laser intensity. Intensity of laser points was initially normalized by removing range effect only. However, microsite topographic factor, such as slope angle,was not normalized due to difficulty of automatic calculation.

KEY WORDS: LiDAR, Intensity, Normalization, Reflectance, Range

1. INDRODUTION

LiDAR is an emerging technology measuring precise 3D surface in diverse applications of urban modelling, forestry, and bathymetry. Most LiDAR-related studies have focused on the accurate measurement of surface height, such as DSM and 3D modelling, and only a few studies have presented calibration and application of intensity data. The intensity of laser point is recorded by the power of backscattered energy, which is mainly affected by target reflectance and range (Wehr and Lohr, 1999; Wagner et al., 2006; Ahokas et al., 2006). In addition, viewing geometry, atmospheric condition and humidity of surface are also effective factors of intensity (Optech, 2005). Although intensity data has not been goodenough to be used for the automatic classification of surface materials, there were a few cases to show the. Song et al. (2002) assessed statistical separability among several cover classes using filtered laser intensity image. Wagner et al. (2006) used full-waveform ALS (airborne laser scanner) for the land cover classification. The calibration of LiDAR intensity has been conducted in laboratory conditions to normalize the scan angle effect (Kaasalainen et al., 2005). Recently, Ahokas et al. (2006) tried to calibrate airborne laser intensity obtained from reference tarps with known flying height and atmospheric transmittance. These preliminary studies were mainly focus on the calibration of only effective factors namely, target reflectance and range. Studies on laser intensity have not been delved enough in the respect of viewing geometry, atmospheric condition and surface moisture condition. From our previous study, we found that reflectance and range were main factor that affected laser intensity. Furthersurface slope could influence to laser intensity in addition to reflectance and range (Shin et al. 2006).

This study attempts to normalize intensity by removing range differences based on investigation of the relationship between intensity and geometric/topographic factors such range, LIA(local incidence angel), scan angle, ground height, slope and aspect as well as target reflectance.

2. DATA AND STUDY AREA

The study area is located in a a mountainous national park in the middle part of South Korea. As seen in Figure 1, major land cover types in this region are forest, rice paddy, other crop lands, and asphalt roads, concrete roads, gravel streets, and dirt roads. Dominant tree species are oak (*Quercus*), larch (*Larix leptolepis)* and Korean pine (*Pinus koraiensis)* Airborne laser scanner, OPTECH ALTM 3070, wass used to obtain LiDAR data on 28th April 2004 with 60% overlapped three flight lines (Figure 1). Flight height is about 1800m and scanning angle is ±25°. The laser pulse was operated at 1064nm wavelength and records multiple backscattered returns: first, last and singular returns. Singular returns mean that the backscattered signal coincides at the first and last return. As laser signals are backscattered from artificial structures such as buildings, the first and last returns are backscattered at the same location, which are called 'singular returns'. However, laser signals are transmitted through vegetation canopy, the first and last echoes are recorded separately. In this study, the singular returns are extracted from the laser signals of the one flight line to simplify viewing geometry and transmitted pulse power.

Figure 1 shows the high-resolution CCD image that is simultaneously taken with LiDAR overlaid with flight lines.

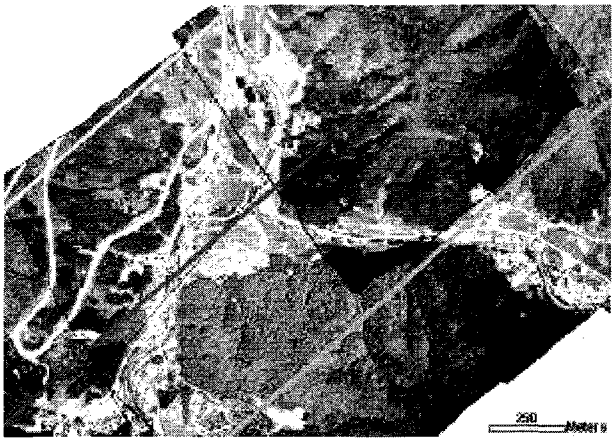

Figure 1. Flight lines overlaid with high-resolution CCD images simultaneously obtained with LiDAR data over study area

Forest stand maps and digital topography maps were used to locate sample plot along with the aerial image. In addition, we measured spectral reflectances on several ground plot (1 plot per each land use type) using a GER 2600 spectro-radiometer at the end of April, 2006. 3D coordinate of laser points and trajectory data are used for calculating range and geometric/topographic conditions of surface. In calculating topographic conditions, DEM is roughly made by interpolation of last points.

3. RANGE NORMALIZATION

3.1 Influential Factors to Laser Intensity

In previous study, 90 sample plots were selected to analyze the effect of independent variables such as reflectance, range and geometric/topographic factors. Each sample plot composes of 40~50 points within 6 by 6 m^2 it is assumed to have the same reflectance at 1061.4 nm of GER instrument.

From these 90 sample plots, we found that laser intensity showed positive linear relationship with field-measured reflectance (figure 2a). In general, reflectance and intensity show the linear relationship. However, depending on cover types, there were some discrepancies that might come from the seasonal variations of vegetation and water, in which the exact condition related to the water conditions, atmospheric condition, and growth status of vegetation at the time of LiDAR data acquisition. Laser intensity shows reverse relationship with range which also related strongly with ground height and scan angle (figure 2b). Third, the slope of objects has negative relationship with intensity (figure 2c). The influence of slope may be associated with laser divergence yielding large footprints. At last, LIA and aspect did not show any clear trend with laser intensity. Because almost singular returns are backscattered on top of tree, singular returns from canopy may not be influenced by topography. So in this study, intensity was not normalized by slope.

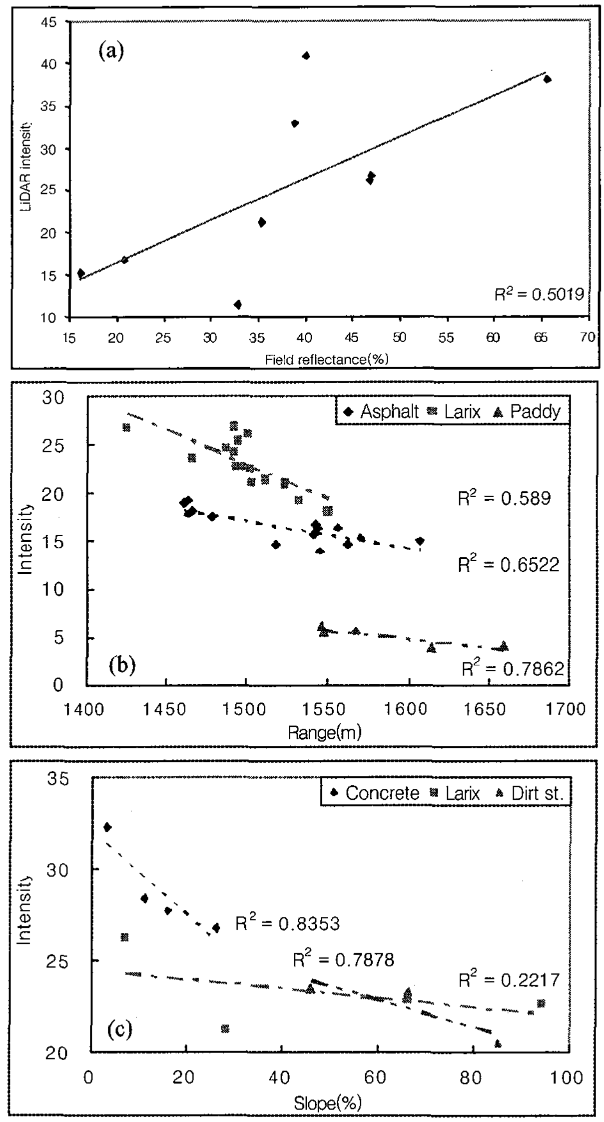

Figure 2. Influences of reflectance(a), range(b) and slope of target surface(c) to laser intensity.

3.2 Range Normalization of Laser Intensity

In recent study by Wagner et al. (2006), the laser intensity is inversely proportional to R^2 for homogenous targets filling the full footprint. Using this relationship, we can normalize the range effect, which is directly dependent on flying height (Ahokas et al., 2006).

$$I_{scaled,j} = I_j \frac{R_j^{\ 2}}{R_{ref}^{\ 2}} \tag{1}$$

I_j = intensity of laser point j,
R_{ref} = reference range,
R_j =range of laser point j.

In this study, transmitted pulse power was not considered since the transmitted pulse power along a single flight line is the same. . Then, intensity of each laser point was normalized to the laser intensity of the shortest range (1313.58m).

Fourteen samples of asphalt road were used to test normalization effect which is invariant man-made material. For easy visualization of normalization effect, singular laser points were interpolated to raster image. Figure 3(a, b) is interpolated raster images (1m resolution) by nearest neighbour method before and after the range normalization. Figure 3a clearly shows the pattern of decreasing intensity value over the homogeneous target (such as road) before range normalization. Brightness of asphalt road at long range is darker than short range.

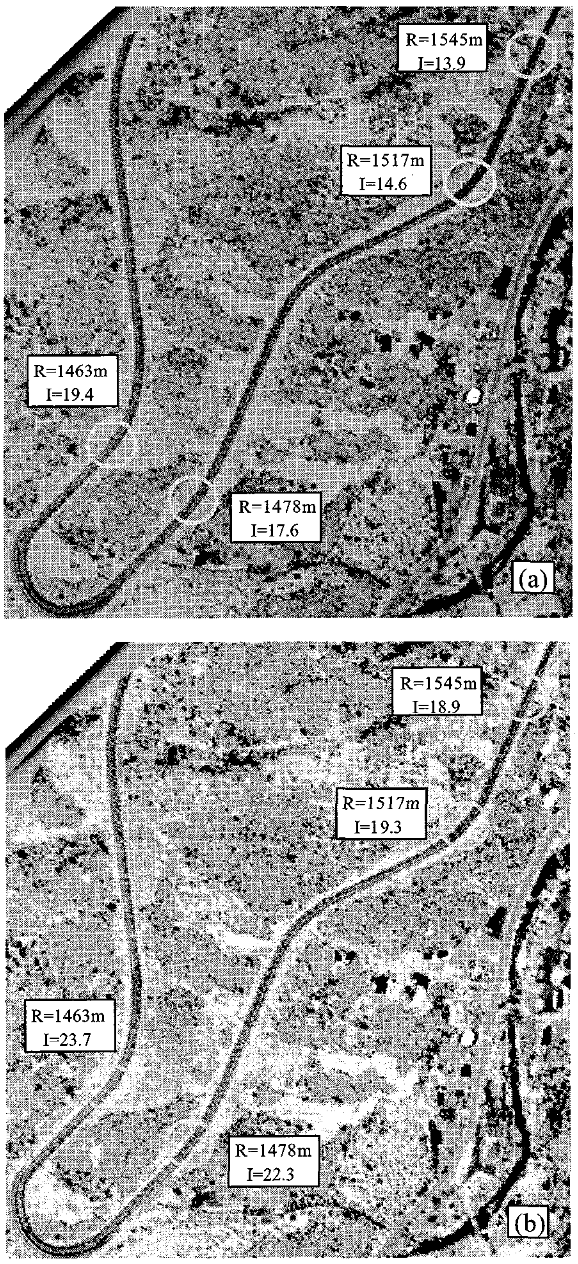

Figure 3. Laser intensity image of before(a) and after(b) the normalization by removing range difference (R : Range at the center of sample plot, I : average intensity of sample plot).

After the range normalization, intensity seems to be normalized although there is still a little variations (figure 3b). Figure 4 shows statistical change of average intensity after range normalization at sample plots extracted from asphalt road. Difference among average values of normalized intensity is more reduced than average values of non-normalized intensity although the minor downward pattern still remains. If the range is only factor that affect the laser intensity, the normalized intensity in figure 4 should have been the same regardless of the range. However, other factors may affect to the laser intensity such as surface water condition or local geography (slope, LIA).

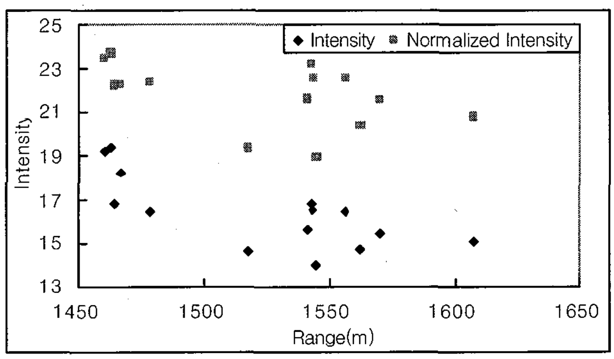

Figure 4. Average laser intensity of asphalt road after the range normalization

4. CONCLUSION

There are several factors that influence laser intensity, which includes range, target reflectance, slope, and surface conditions. In this preliminary study, we generated a normalized laser intensity image by removing the range effect. Although the variation of laser intensity over the same target is somewhat reduced after the normalization, the laser intensity is not completely normalized. This may suggest that there are other factors that may affect laser intensity. Microsite topographic factor and surface moisture condition could be such factor to be considered in laser intensity normalization.

Acknowledgement

LiDAR data was supported by HIST(Hanjin Information Systems & Telecommunication Co.).

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