Characteristics of Intensity Signal from Airborne LiDAR Data

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Abstract

Laser technology has been applied to diverse applications with the advantages of accurate 3D information. Furthermore, LiDAR intensity, backscattered signal power, might provide us additional information regarding surface materials. The level of LiDAR intensity depends on target reflectance, moisture condition, range, and viewing geometry. However, laser intensity have not been fully studied yet. This study purposes to investigate the characteristics of LiDAR intensity. Usually, the high density of LiDAR point clouds is resulted from overlapped scanning data from neighboring multiple flight lines. Since the high density data is too complex to analyze the influential factors of laser intensity, the data from one flight line are extracted to simplify the geometric conditions such as scan angles and transmitted pulse power. Laser intensities of sample plots chosen by reference data and ground survey are then statistically analyzed with independent variables including reflectance, range and geometric/topographic factors (scan angle, ground height, aspect, slope, local incidence angle: LIA). Target reflectance, range between sensor and target and surface slope could be the main factors to influence the laser intensity.

Introduction

LiDAR is an emerging technology measuring precise 3D surface in diverse applications of forestry, urban modeling, and bathymetry. Most LiDAR researches have focused on the accurate measurement of surface height, such as digital surface model (DSM) and 3D modeling, and only a few studies have presented calibration and application of intensity data. The intensity of LiDAR 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). Moreover viewing geometry, atmospheric condition and humidity of surface are also effective factors of intensity (Optech, 2005). Laser intensity data may not sufficient enough to classify objects but its potentiality have been reported by a few studies. Song et al. (2002) assessed separability using statistics of filtered laser intensity image. Wagner et al. (2006) used full-waveform ALS (airborne laser scanner) for classification with characteristics and calibration theories from radar equations. The calibration of LiDAR intensity has been tried to use variation of intensity measured in laboratory according to scan angle (Kaasalainen et al., 2005). Subsequently, Ahokas et al. (2006) corrected intensity of tarps with constant reflectance acquired by ALTM 3100 depending on flying height and atmospheric transmittance. Most researches have tried analysis and calibration of only effective factors namely, target reflectance and range. Studies on laser intensity have not been enough in the respect of viewing geometry, atmospheric condition and surface humidity. Therefore, this study attempts to investigate the relationship between intensity and geometric/ topographic factors such range, scan angle, ground height, slope and aspect as well as target reflectance.

Study Area and Data

The study area is a mountainous national forest in the middle part of South Korea. The study area also includes other land cover types of asphalt roads, concrete roads, gravel streets, dirt streets, crop land, grass land and rice paddy. Dominant tree species are oak (*Quercus*), larch (*Larix leptolepis)* and Korean pine (*Pinus koraiensis)*. Airborne laser scanner, OPTECH ALTM 3070, was 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˚. This airborne laser scanner had 1064nm wavelength and recorded multiple backscattered returns: first, last and singular returns. Singular returns mean the backscattered signal recorded twice as the first and last return. As laser signals are backscattered from man-made 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 under vegetation canopy, the first and last echoes are recorded respectively. In this study, the singular returns are extracted from the laser signals of the one flight line for characteristics analysis of LiDAR intensity.

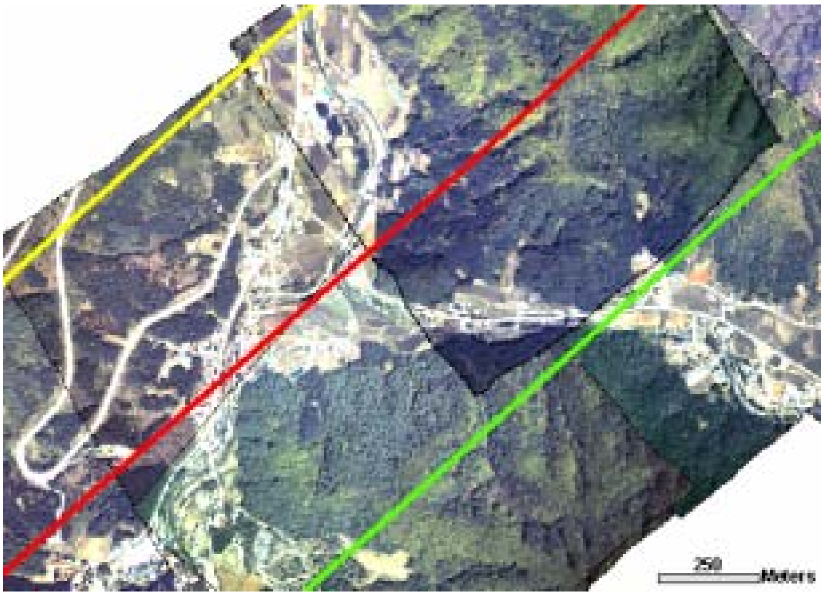

Figure 1. Flight lines overlaid with high-resolution CCD images simultaneously obtained with LiDAR data over study area

Forest stand maps and digital topography maps were used to locate sample plot as well as other references. In addition, several ground truth target reflectance (1 plot per each land use type) are directly measured by 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 echo points including singular echo points.

Data Processing and Sample plot selection

Similar to aerial photographs, flight lines of LiDAR are overlapped for obtaining high point density and gap prevention. Laser intensity backscattered from the same object is predicted to be almost constant. However, due to different transmitted pulse power and geometric condition of each flight line, overlapped points from adjacent flight lines show large variation of intensity on the same target (Figure 2a). Laser points from one flight line and singular returns are extracted to simplify the geometric conditions, such as scan angles and transmitted pulse power. Figure 2a shows the laser points from multi flight lines, while Figure 2b shows the laser points from one flight line. Table 1 shows basic statistics of singular laser points' intensity within a box on figure 2. In Table 1, the intensity from one flight line has smaller standard deviation than the intensity of multi flight lines.

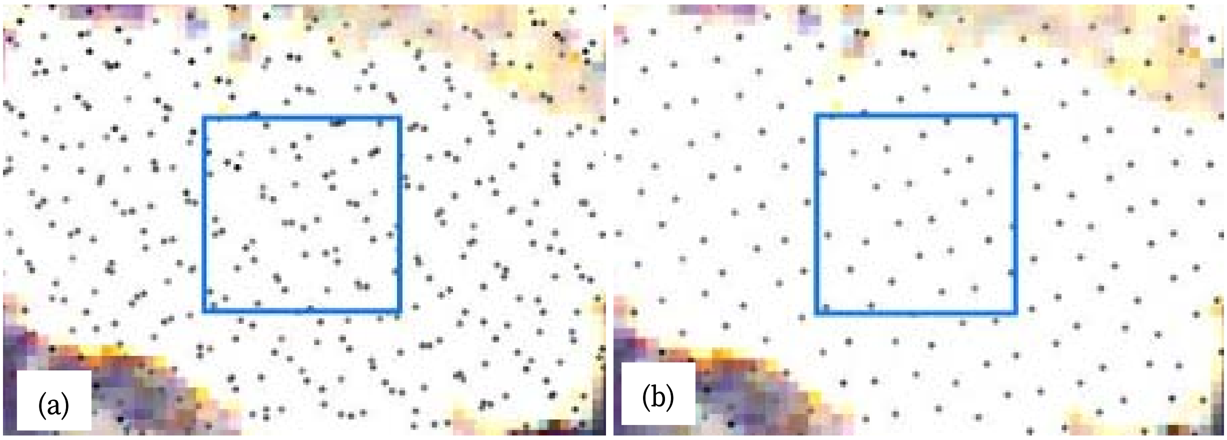

Figure 2. Laser points of concrete from overlapped multi flight lines (a), and from single flight line (b).

Reflectance, range, local incidence angle (LIA, horizontal, vertical) and other geometric/topographic factors (scan angle, ground height, slope and aspect) are chosen to be investigated to analyze the critical factors to determine characteristics of laser intensity. Based on the reference data, 90 sample plots are set for analysis. Each sample plot composes of 40~50 points within 6 by 6 meters and it is assumed to have the same reflectance at 1061.4 nm.

Table 1. Basic statistical measures of laser points' intensity from overlapped flight lines and single flight line shown in a box of figure 2.

Flight line	No. of points	Minimum	Maximum	Mean	Standard Deviation
Overlapped	62	8	43	31.35	6.07
Single	29	30	43	35.54	3.16

Statistical Analysis

To investigate the characteristics of intensity, the relationship between the field measured reflectance with a GER instrument and LiDAR intensity is shown in Figure 3. 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 were not quite known.

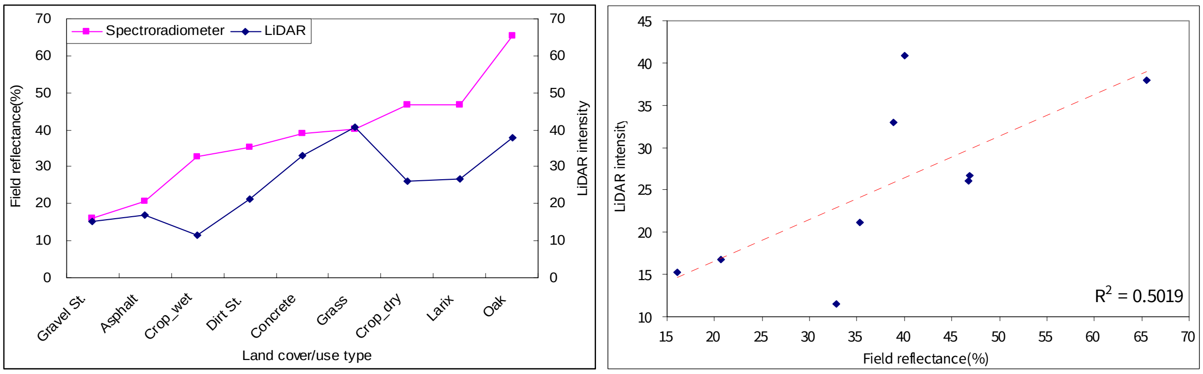

Figure 3. The relationship between field-measured reflectance and LiDAR intensity according to land cover/use type (a) and linearity of both (b).

4~5 sample plots with the same condition are selected to find the relationship with intensity. Figure 4 comprehensively illustrates the relationships between the intensity and one of seven geometric and topographic variables according to land use type. It is obvious that several factors are influential to the laser intensity. First, laser intensity shows reverse relationship with range. That is, if an object is located at the long distance from the laser instrument, the backscattered intensity is getting weaker. Second, scan angle that is something to do with range also negatively affects intensity. Third, the slope of objects has strong negative relationship with intensity. At last, ground elevation that is directly related to the range shows positive relationship with laser intensity. Any clear trend with LIA and aspect has not been found in this preliminary analysis. Because almost singular returns are backscattered on top of tree, singular returns from canopy may not be influenced by topography. The results of linear multiple regressions with all variables are in 95% confidence level. Consequently, reflectance, range and slope among geometric and topographic variable are the critical factors to affect intensity, while some of geometric and topographic variable are related to ranges.

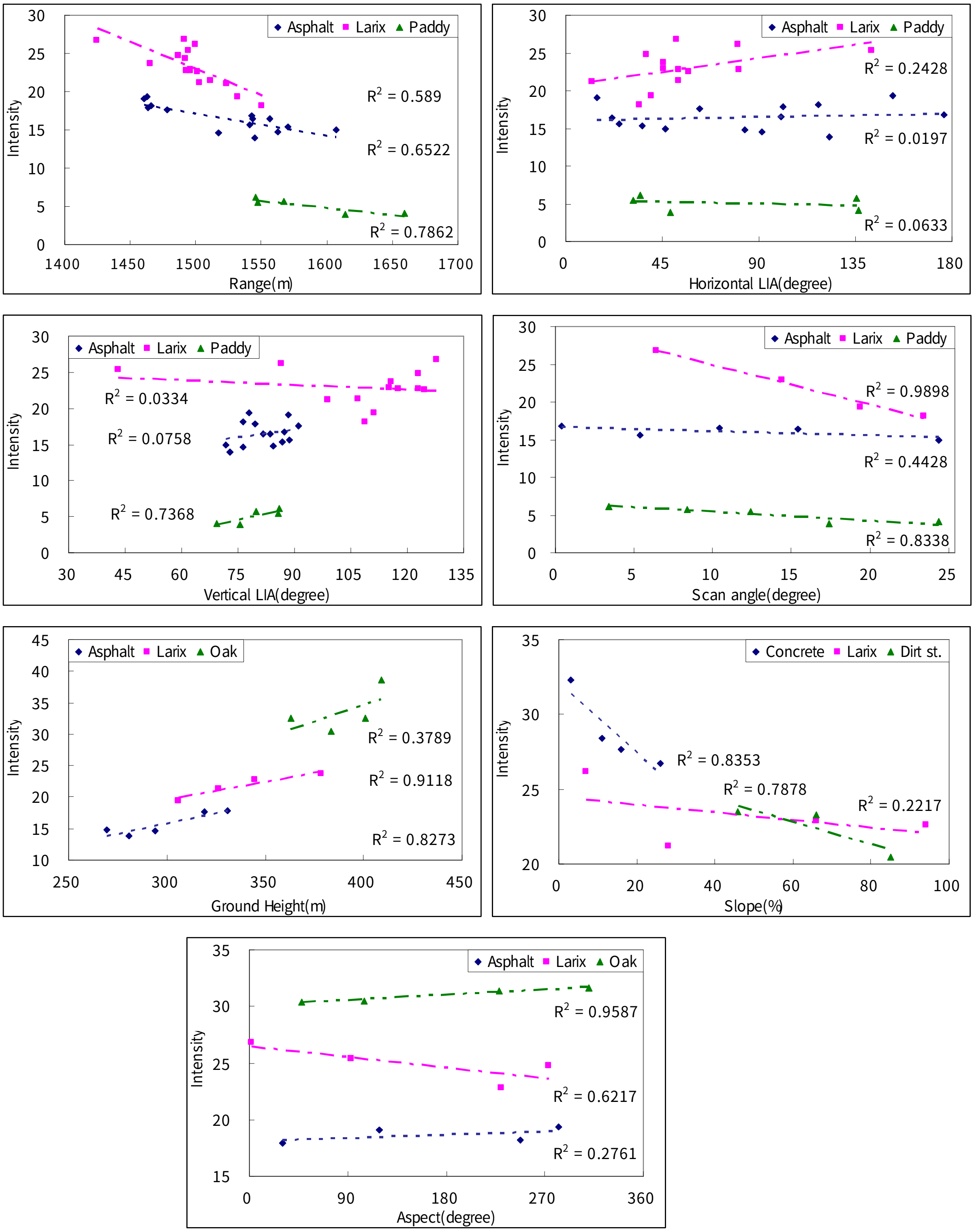

Figure 4. Plots to represent relationships of intensity with Range, LIA, geometric/topographic conditions.

Conclusion

In this preliminary study, characteristics of LiDAR intensity data are investigated by several parameters that might have influence on laser intensity. To simplify viewing geometry, points from single flight line were extracted from adjacent overlapped flight lines. The result of statistical analysis reveals reflectance and range are the main factors influencing on laser intensity. First of all, laser intensity recorded backscattered signal power is strongly affected by the target reflectance. The secondary factor is range that is distance between the instrument and an object. Additionally slope is another factor to affect intensity. The influence of slope may be associated with laser divergence yielding large footprints. Further study could consider normalization of laser intensity in the respect of range and slope. The normalized intensity representing near-infrared reflectance could be a high-resolution data source expanding the radiometric use of LiDAR.

Acknowledgement

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