Investigation of Airborne LIDAR Intensity data

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Abstract: LiDAR(Light Detection and Ranging) system can record intensity data as well as range data. Recently, LiDAR intensity data is widely used for landcover classification, ancillary data of feature extraction, vegetation species identification, and so on. Since the intensity return value is associated with several factors, same features is not consistent for same flight or multiple flights. This paper investigated correlation between intensity and range data. Once the effects of range was determined, the single flight line normalization and the multiple flight line normalization was performed by an empirical function that was derived from relationship between range and return intensity

Keywords: LiDAR, Intensity, Normalization

1. Introduction

LiDAR system provides intensity data that is measurement of the return signal strength and reflects material characteristics of the targets. However, in general return intensity is influenced by several factors so that the measured return intensity may not be consistent for a given target.

When LiDAR intensity data is used for extracting qualitative information of the features, intensity value has to represent only reflectance of the surface not to be affected by others. It is important that intensity value is corrected for variation by several factors one of which is the range.

A number of research works have been performed on the classification utilizing LiDAR intensity data. However, there was commonly not considered the intensity variation by several factors. Hug (1997) showed that the reflectance criterion improved the discrimination reliability between artificial surface objects (buildings) and natural objects (trees and bushes).

The aim of our research is to analyze geometric parameter which influences variation of intensity and to verify the feasibility to normalize. This will improve the accuracy of analysis of the features characteristics. After the corrections were applied, intensity variation was decreased about 20% compared with the original data. The influence of correlation between the intensity value and range were deduced, which demonstrated that range could be used to correct future intensity data.

2. LiDAR Intensity

The active sensor typically the optical sensor measures the reflected energy that is illuminated by the sun. However, LiDAR is an active sensor, which supplies its own source of energy to illuminate features of interest. LiDAR sensor uses light in the near infrared spectrum, which emits a beam of light and records the time and intensity of the beam returned to the aircraft. The intensity value can indicate the characteristic of the targets.

LiDAR intensity data is the strength of laser pulse which is reflected from the target. The recorded data is the analogue electrical signal which is quantized positive integer value using a process called analog-to-digital (A-to-D) signal conversion. The individual return value corresponds to the average radiance measured in each point.

For ALTM instrument, intensity data is produced by the intensity module, which measures the peak amplitude of the first and last return pulses. The intensity return values are considered relative rather than absolute measurements. The intensity range is from 0 to 8160, 0 being a very weak return and 8160 being a very strong return. The return intensity is based on several factors such as, flying elevation, atmospheric conditions, directional reflectance properties and the reflectivity of the return target. For these reasons the measured return intensity may not be consistent for a given target (Jonas, 2002).

Baltsavias (1999) have provided theoretical overview of the primary factors affecting the strength of laser pulse of LiDAR system.

The received energy is:

$$P_s(R) = P_t \frac{P_t(R)}{\pi} \frac{A_r}{R^2} \eta_o \eta_a (R) \tag{1}$$

Where $P_s(R)$ = received energy

P_t = transmitted energy

$P_t(R)$ = "effective Lambertian" reflectivity of the target

A_r = area of receiving optics

R = slant range to the target from sensor

η_o = optical transmission efficiency

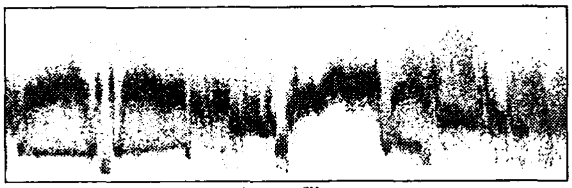
$\eta_a(R)$ = transmission efficiency of the atmosphere between sensor and target

P_t, A_r, η_a : LiDAR system hardware parameter

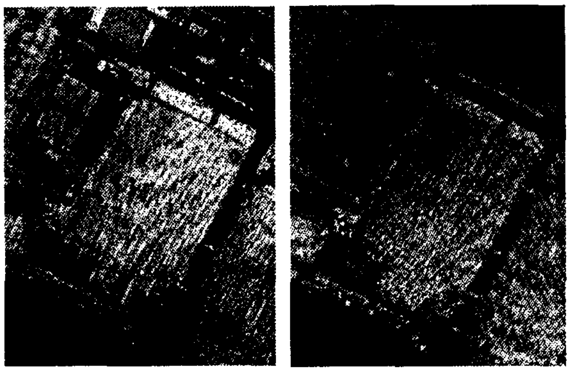
$P_t(R), \eta_a(R), R$: operating parameters

3. The proposed approach

The several factors can cause the variation of intensity value of the same surfaces and the discrepancy between overlapping area. Figure 1 illustrates this phenomenon.



(a) profile



(b) intensity plot of flight 2 (c) intensity plot of flight 3

Fig. 1. Discrepancies between overlapping flight paths.

As shown in eq. (1), operating environment parameters which affect the intensity value are reflectivity of the target, slant range to the target from sensor and transmission efficiency of the atmosphere. On the assumption that homogeneous surfaces have same influence with the exception of slant range, we analyzed correlation between intensity and range.

In most previous researches, intensity image rather than irregular point intensity has been investigated. In this study we used original raw data which is irregularly distributed instead of intensity image. Also slant range of each point was computed by using LiDAR orientation information.

1) Training Fields Selection and Statistics Extraction

To investigate the characteristics of intensity, training fields are selected with respect to terrain surface which is identified and classified by aerial image portraying the test area. After then, the statistics about each terrain surface are computed.

2) Correlation between Range and Intensity value

In general, LiDAR intensity value is inversely proportional to slant range which is distance from LiDAR sensor to target point. Slant range varies in terms of the height difference and the angle of scanning of measured geometry. The smaller the scanning angle is, the larger the intensity value is. Even though the scanning angle points to the same direction, the intensity value will vary depending on the height. The higher the terrain surface is, the stronger the intensity value is.

In our study, the terrain surface is classified into 8 classes. For each class, the slant range of each laser point is computed using orientation information of LiDAR sensor and the average of intensity value for each slant range(R) was determined. With slant range data and their corresponding intensity data, the regression analysis for each class was performed.

3) Normalization

It is anticipated that the increase of slant range will cause the decrease of intensity value. Even for flat terrain such as playground, the intensity value will vary over the terrain. To remove the variation of intensity value over the same class of classification, the intensity value is normalized using the result of regression analysis.

4. Experimental Results

1) Test Data

The study area is located in Incheon city, Korea and contains various topographical features such as building, grass, tree, asphalt road, concrete road, playground and so on. The laser data was acquired by optecn ALTM 3070 LiDAR system. The data was collected from an altitude of about 762m with 20-degree field of view (half angle) at 47 Hz scanner frequency and 70 KHz pulse rate which resulted in a point density of 0.728 points/m^2. Data was collected in north-south flights followed by east-west ones.

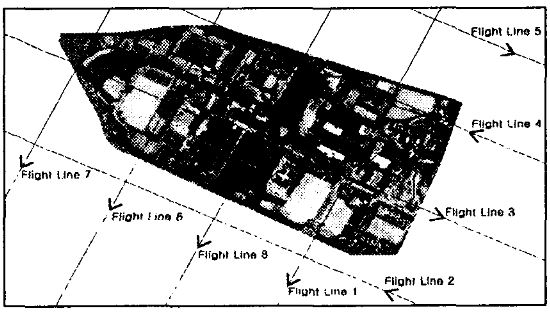


Fig. 2. The study area with flight paths.

The dataset consists of 4 strips flown in north-south direction and 4 strips flown in east-west direction. Strips are shown in Figure 2 and LiDAR data specification is summarized in Table 1.

Table 1. LiDAR data.

Flight Profile		LIDAR Settings	
Altitude (m AGL)	762	System PRF (kHz)	70.00
Pass Heading (deg)	115	Scan Freq (Hz)	47
Overlap (m)	277.345	Scan Angle +/-	20
Speed (m/s)	66.9	Desired Res (m)	0.728
Turn Time (min)	7	Cross Track Res	0.745
Passes	4	Down Track Res	0.711
Pass Spacing (m)	277.35	Swath (m)	554.69

2) Intensity Characteristics of Surface Classes

The statistics of intensity value over each terrain class are computed to explore the discriminative reflection characteristics. The statistics are represented in Figure 3 and listed in Table 2.

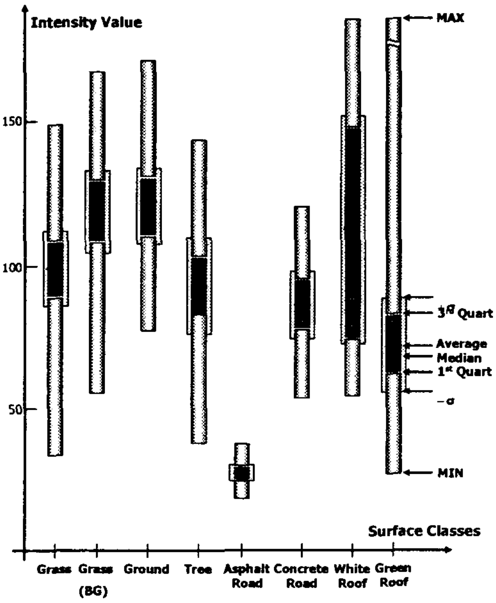


Fig. 3. Box plot of surface classes.

It is shown in Figure 3 that some of surface classes have discriminative characteristics. However, the characteristics are not enough for classification of various classes without additional information. The variation of intensity range for each class is quite wide and some classes have similar reflectance characteristics. Therefore, minimizing variation of intensity range is required for improving the performance of classification process.

3) Correlation between Range and Intensity

In our study, the terrain surface is classified into 8 classes. Among terrain surface classes, we selected for investigation the playground class which is covered in large part of test area and is located across the flight direction. For the playground class, the slant range of each laser point is computed using orientation information of LiDAR sensor and the average of intensity value for each slant range(R) was determined. With slant range data and their corresponding intensity data, the regression analysis was performed.

Table 2. Statistics of intensity DN value.

Class	Flight line	Min	Max	Mean	Median	Std. Dev.
Grass	Fl 1	74	134	100	100	11
	Fl 2	33	130	100	100	12
	Fl 3	76	136	102	101	11
	Fl 6	63	118	87	87	9
	Fl 8	80	148	112	11	12
Grass (baseball ground)	Fl 2	55	128	101	101	9
	Fl 3	76	166	125	125	11
	Fl 4	58	135	111	111	9
	Fl 6	72	160	122	122	11
	Fl 7	72	167	127	127	11
Ground	Fl 2	78	147	111	111	9
	Fl 3	92	161	126	126	11
	Fl 6	94	170	131	131	11
	Fl 7	85	148	116	115	10
Tree	Fl 1	44	134	94	96	16
	Fl 2	39	121	86	88	16
	Fl 3	47	125	90	92	15
	Fl 8	38	143	99	100	18
Asphalt road	Fl 3	19	37	27	27	3
	Fl 4	19	32	26	26	2
	Fl 6	20	36	28	28	3
	Fl 8	19	36	27	27	3
Concrete road	Fl 2	53	97	76	77	8
	Fl 3	63	120	88	88	11
	Fl 6	57	119	91	91	11
	Fl 8	60	115	88	88	11
White Roof	Fl 3	59	185	133	152	44
	Fl 4	55	141	102	107	26
	Fl 6	56	109	71	68	14
	Fl 8	71	182	128	141	36
Green Roof	Fl 3	54	142	75	74	10
	Fl 4	41	107	61	60	8
	Fl 6	25	151	61	59	12
	Fl 8	59	181	87	84	15

The correlation results about 8 surface classes are shown in Table 3. As shown, the correlation between range and intensity value is not always inversely proportion.

4) Empirical Intensity Normalization

For playground class which has wide range scope, we generated empirical function that was derived from relationship between range and return intensity.

LiDAR data of the playground class was appeared in 1, 2, 3 and 8 flight lines. Among these data, the playground data in the second flight line which has the widest range scope was selected for reference class. The third flight line which has a similar range scope was selected for target class. We performed normalization based reference class. The statistics are represented in Figure 4 and listed in Table 4 and Table 5.

Table 3. Correlation between intensity and range.

Class	Flight line	R	R^2	Range(m)	Points
Grass	Fl 1	-0.95	0.91	825~828	307
	Fl 2	-0.99	0.99	797~801	420
	Fl 3	0.99	0.99	781~783	461
	Fl 6	-0.53	0.28	805~813	792
	Fl 8	-	N/A	780~781	415
Grass (baseball ground)	Fl 2	0.14	0.02	825~839	1704
	Fl 3	0.20	0.04	775	1784
	Fl 4	-0.98	0.97	794~800	1654
	Fl 6	0.43	0.19	786~798	1585
	Fl 7	-0.95	0.90	793~796	2000
Ground	Fl 2	-0.34	0.12	805~822	3917
	Fl 3	-0.91	0.82	775~779	3996
	Fl 6	-0.93	0.86	767~772	3776
	Fl 7	0.17	0.03	811~824	4048
Tree	Fl 1	-0.63	0.40	799~804	340
	Fl 2	0.82	0.67	782~791	299
	Fl 3	-0.48	0.23	771~779	336
	Fl 8	-0.77	0.59	770~775	310
Asphalt road	Fl 3	-0.93	0.86	775~777	247
	Fl 4	-0.40	0.16	771~774	215
	Fl 6	0.85	0.73	769~772	244
	Fl 8	-0.84	0.70	792~796	225
Concrete road	Fl 2	-0.94	0.89	814~822	219
	Fl 3	-	N/A	775~776	227
	Fl 6	-	N/A	775~776	220
	Fl 8	-	N/A	795~796	215
White Roof	Fl 3	-0.82	0.67	759~762	38
	Fl 4	-0.95	0.90	758~761	44
	Fl 6	-0.94	0.88	777~780	23
	Fl 8	-0.97	0.95	763~766	38
Green Roof	Fl 3	-	N/A	758~759	530
	Fl 4	-0.77	0.59	760~765	495
	Fl 6	-0.73	0.53	774~781	478
	Fl 8	-0.98	0.97	763~765	542

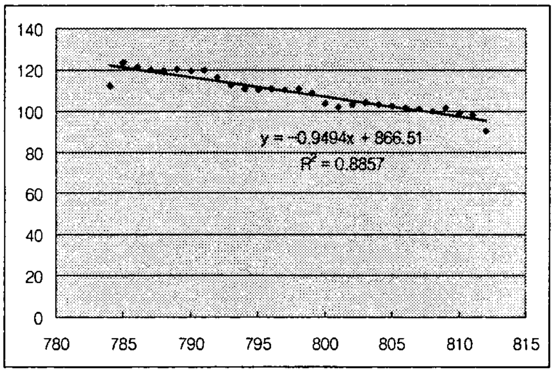


Fig. 4. Regression results for playground class.

Table 4. Statistics of reference class (playground).

Class	Flight line	Before Normalizing	After Normalizing
Ground (Fl 2)	Min	38	35.9
	Max	183	168.8
	Mean	111	95.6
	Median	111	95.6
	St. Dev	14.3	10.5

Followed Table 5 is indicated that the variation is reduced between before data and after one. However, the effect of range still exists.

Table 5. Statistics of target Class(playground).

Class	Flight line	Before Normalizing	After Normalizing
Grass (Fl 3)	Min	80	64.7
	Max	175	143.5
	Mean	120	96.9
	Median	120	96.7
	St. Dev	11.6	9.8

5. Conclusions

In this paper, we investigated the laser reflectance characteristics of various classes such as grass, ground, tree, asphalt road, concrete road, white roof and green roof. Moreover, the correlation between intensity and range was examined for exploring the discriminative property of laser intensity. It could be mentioned that the correlation between intensity and range is not consistent over terrain classes. In addition, the reflectance characteristics of terrain classes vary flight line by flight line so that the classification process of lidar intensity should be further investigated.

Acknowledgement

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