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Application of Terrestrial LiDAR for Displacement Detecting on Risk Slope

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위험 경사면의 변위 검출을 위한 지상 라이다의 활용

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Abstract In order to construct 3D geospatial information about the terrain, current measurement using a total station, remote sensing, GNSS(Global Navigation Satellite System) have been used. However, ground survey and GNSS survey have time and economic disadvantages because they have to be surveyed directly in the field. In case of using aerial photographs and satellite images, these methods have the disadvantage that it is difficult to obtain the three-dimensional shape of the terrain. The terrestrial LiDAR can acquire 3D information of X, Y, Z coordinate and shape obtained by scanning innumerable laser pulses at densely spaced intervals on the surface of the object to be observed at high density, and the processing can also be automated. In this study, terrestrial LiDAR was used to analyze slope displacement. Study area slopes were selected and data were acquired using LiDAR in 2016 and 2017. Data processing has been used to generate slope cross section and slope data, and the overlay analysis of the generated data identifies slope displacements within 0.1 m and suggests the possibility of using slope LiDAR on land to manage slopes . If periodic data acquisition and analysis is performed in the future, the method using the terrestrial lidar will contribute to effective risk slope management.

요 약 기존에는 지형에 대한 3차원 공간정보 구축을 위해 주로 토털스테이션을 이용한 현황측량, 원격탐사, GNSS(Global Navigation Satellite System) 등의 방법이 주로 활용되어 왔다. 하지만 토털스테이션이나 GNSS는 대상지에 접근과 많은 관측을 요구하기 때문에 작업효율과 경제성이 떨어지며, 항공사진이나 인공위성영상은 지형의 3차원 형상을 취득하기 어렵다는 단점이 있다. 지상 LiDAR(Light Detection And Ranging)는 측정 대상물에 무수히 많은 레이저를 주사하여 X, Y, Z 좌표와 형상에 대한 정보를 얻을 수 있으며, 자료처리의 자동화가 가능한 장점이 있다. 본 연구에서는 지상 LiDAR를 이용하여 사면의 변위를 검출하고자 하였다. 연구대상 사면 3개소를 선정하고, 2016년과 2017년에 대상 사면에 대한 자료를 취득하였으며, 자료 처리를 통해 경사면의 형상과 단면에 대한 데이터를 생성할 수 있었다. 또한 생성된 데이터의 중첩분석을 통해 효과적으로 사면의 변위가 0.1m 이내임을 파악함으로써, 위험사면의 관리를 위한 지상 LiDAR의 활용 가능성을 제시하였다. 향후 주기적인 데이터 취득 및 분석이 이루어진다면 지상 LiDAR를 이용한 방법은 효과적인 위험사면 관리에 기여할 것이다.

Keywords : Geospatial Information, Light Detection And Ranging, Mesh, Pointcloud, Slope Displacement

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1. Introduction

Recently, there have been frequent heavy rains due to climate change, and slope failure has occurred frequently, resulting in increasing life and property damage every year[1-2]. The slope failure is the most desirable method to find the cause of collapse in advance and to eliminate the cause and to take preventive measures, but finding the cause of collapse in advance requires economical and technological cost and technical force[3]. Also, when the slope collapse occurs, it is important to find a permanent recovery plan though the cause of the cause is important[4]. It is necessary to construct precise geospatial information about the slope in order to find the risk of collapse in advance, to analyze the cause after the collapse, or to establish a permanent recovery plan. The terrestrial LiDAR can acquire 3D geospatial information of the object, and it is increasingly used for slope topography survey, structural survey, current survey, cultural asset survey, shoreline change survey, volumetric survey, and tunnel survey[5-6].

In case of slope, quantitative interpretation method is needed to find risk beforehand or to establish cause analysis or recovery plan after collapse[7]. At this time, topographical information such as slope before collapse, slope after collapse, and section after slope after restoration are required, and ground survey data is also necessary. Especially, accurate geospatial information has a great influence on the accuracy of safety diagnosis. In this study, terrestrial LiDAR was used to obtain slope data and analyzed the applicability of LiDAR. Chapter 2 describes the data acquisition of the study site using Terrestrial LiDAR, and chapter 3 contains the data processing and analysis contents. Fig. 1 shows study flow.

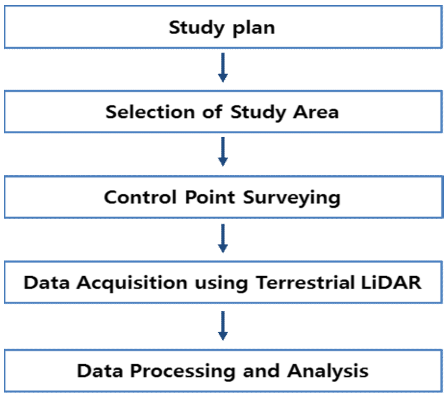


Fig. 1. Study Flow

2. Data Acquisition with Terrestrial LiDAR

Terrestrial LiDAR operates on the same principle as a total station with 3D laser scanning. The distance is measured by receiving a laser reflected in the near-infrared or visible light wavelength band, receiving the returning laser beam from the object, and measuring the horizontal and vertical angles of the laser beam simultaneously with distance measurement. Terrestrial LiDAR has a measurement speed of tens of thousands points or more per second, whereas the conventional total station measures the point by adjusting the angle of the laser beam to a specific point to be measured.

Most terrestrial LiDARs currently in use use pulsed lasers. When pulses are used, the most common way to observe the distance is to measure the round-trip time of the laser pulse and multiply it by the speed of light, taking advantage of the time between the emission and reception of the pulse. The reciprocating time of the laser pulse can be expressed by Equation (1)[8].

$$T_L = 2\frac{R}{C} \tag{1}$$

where, R is distance between distance observer and ground surface, C is speed of light. In Equation (1), the distance error is directly proportional to the time error, and is derived as in Equation (2)[8].

$$\Delta R = \frac{1}{2} c \Delta T_L \tag{2}$$

where, △R is resolution of distance, △ TLisresolutionoftimeobservation. In this study, slopes located in Daejeon were selected as study sites for terrain slope data acquisition using terrestrial LiDAR. Fig. 2 shows onr of target slope and Fig. 3 shows location of the study area.

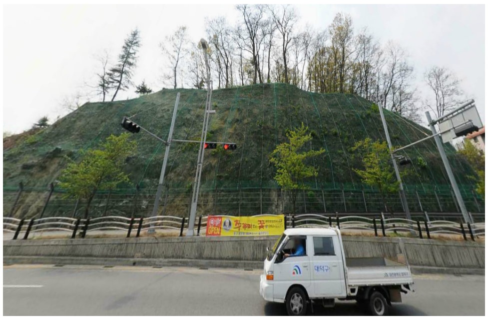


Fig. 2. One of Target Slope

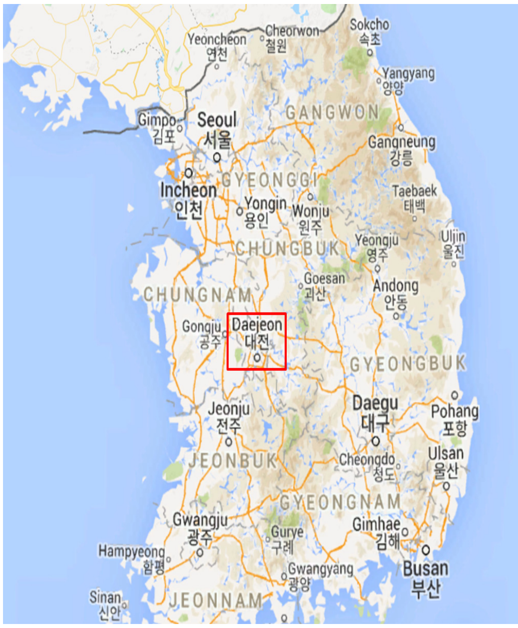


Fig. 3. Location of Study Area

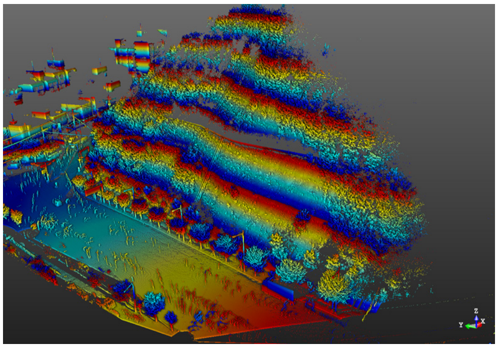
In this study, data of study area were acquired in 2016 and 2017 using two types of terrestrial LiDAR. For the georeferencing of the acquired data, the control points were surveyed by the VRS (Virtual Reference Station) method, and the stations were moved and data were acquired to obtain the data of the entire area. Fig. 4 show terrestrial LiDAR[9][10].

Fig. 4. Terrestrial LiDAR

Table 1. Coordinate of Control Points

Point	X(m)	Y(m)	H(m)
Control Point 1	410811.797	234988.752	71.726
Control Point 2	410751.429	234973.109	76.09
Control Point 3	411865.207	235410.243	79.045
Control Point 4	411972.652	235438.81	71.428
Control Point 5	410999.66	235893.13	126.169
Control Point 6	411035.547	235833.919	119.94
Control Point 7	415139.781	240587.351	92.45
Control Point 8	415117.721	240609.289	94.959
Control Point 9	409924.725	231707.056	72.797
Control Point 10	409886.436	231667.113	75.154
Control Point 11	406622.795	230957.171	95.12
Control Point 12	406558.605	230926.358	92.807
Control Point 13	413351.081	223652.956	242.053
Control Point 14	413457.568	223670.525	246.056

Scanning was performed in 2016 and 2017 and the data was acquired in three stations. Fig. 5 shows the acquired data.



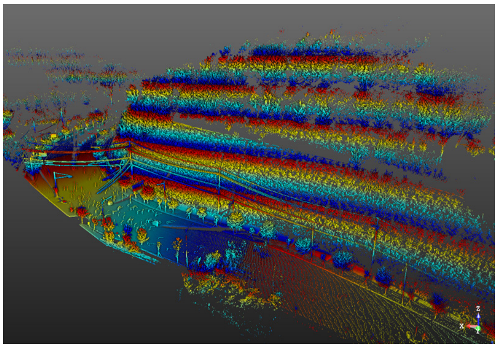


Fig. 5. Scanned Data

3. Data Processing and Analysis

Scanned data with terrestrial LiDAR were converted to las format pointcloud. Since the transformed pointcloud is the shape information without the actual coordinates, georeferencing is performed to the actual position using the coordinates of the controlpoint. Fig. 6 shows data processing work flow.

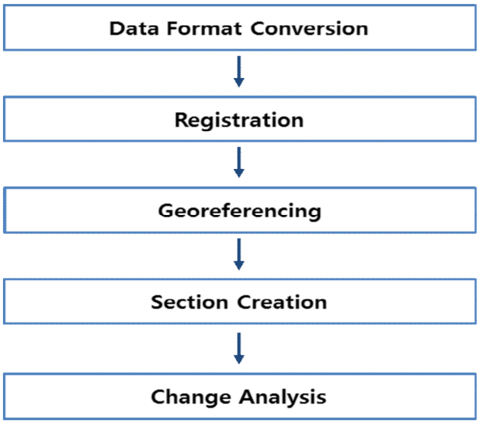


Fig. 6. Data Processing Work Flow

A section was created using the processed pointcloud data. The information on the cross section is very important data for analyzing the stability of the slope, and the cross section created using the scan data can be used for not only a specific section but also any section. Fig. 7 shows the section created using pointcloud.

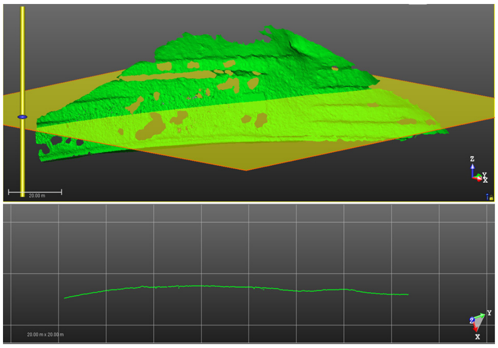


Fig. 7. Section Created using Pointcloud

To analyze the change in cross section, a mesh was created for the slope using data for 2016 and data for 2017. The variation of the slope was calculated by superimposing on the mesh and the result was shown visually. Figure 8 shows the mesh generated from the 2016 data, and Figure 9 shows the mesh generated from the 2017 data. Figure 10 shows the amount of change by mesh overlay.

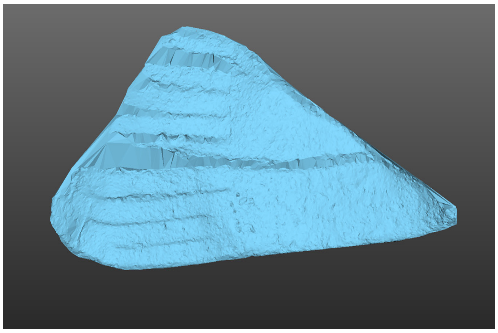


Fig. 8. Mesh data of 2016 – Slope 1

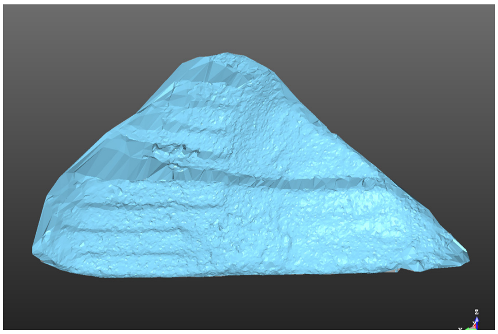


Fig. 9. Mesh data of 2017 – Slope 1

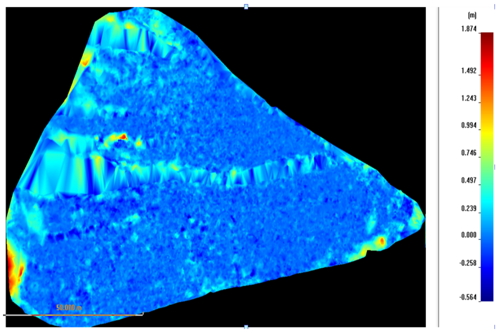


Fig. 10. Amount of Change by Mesh Overlay – Slope 1

Table 2 shows the displacement for the slopes of 2016 and 2017 as a result of the mesh overlap analysis for four slopes.

Table 2. Displacement of Slope

Slope 1			
Displacement (>=Min)	Displacement (<Max)	Points	%
-1	-0.82	3	0.0179
-0.82	-0.64	22	0.1313
-0.64	-0.46	41	0.2447
-0.46	-0.28	116	0.6922
-0.28	-0.1	1751	10.4487
-0.1	0.1	12133	72.4012
0.1	0.28	2203	13.146
0.28	0.46	417	2.4884
0.46	0.64	53	0.3163
0.64	0.82	8	0.0477
0.82	1	2	0.0119
Slope 2			
Displacement (>=Min)	Displacement (<Max)	Points	%
-1	-0.82	12	0.018
-0.82	-0.64	106	0.159
-0.64	-0.46	144	0.216
-0.46	-0.28	458	0.6869
-0.28	-0.1	5812	8.7166
-0.1	0.1	49584	74.3645
0.1	0.28	7086	10.6274
0.28	0.46	1389	2.0832
0.46	0.64	504	0.7559
0.64	0.82	314	0.4709
0.82	1	188	0.282
Slope 3			
Displacement (>=Min)	Displacement (<Max)	Points	%
-1	-0.82	20	0.0327
-0.82	-0.64	37	0.0606
-0.64	-0.46	117	0.1916
-0.46	-0.28	803	1.3148
-0.28	-0.1	12769	20.9067
-0.1	0.1	32486	53.1895
0.1	0.28	8377	13.7157
0.28	0.46	1905	3.1191
0.46	0.64	858	1.4048
0.64	0.82	556	0.9103
0.82	1	340	0.5567

The section with the largest displacement was about 10 cm, which represented about 70% of the total slope displacement. The displacement of 0.6m or more was less than 1% of the total displacement. This seems to be vegetative displacement, and the effect of vegetation needs to be taken into account for this effect. As shown in the results of the analysis in 2016 and 2017, the slopes of the study site did not have large displacement. However, if the slope analysis using terrestrial LiDAR is performed periodically, it will be widely used as data for evaluating slope stability.

4. Conclusions

In this study, terrestrial LiDAR was used to acquire and analyze slope. The results of the study are as follows.

1. Data were collected using LiDAR in 2016 and 2017, and data processing enabled us to effectively generate georeferenced pointcloud data of slopes.
2. To analyze the displacement of the slope, the mesh was generated using the acquired data and the displacement were calculated by overlap analysis. The displacement of the slope of the study area was mostly less than 0.1m, which indicates that no significant displacement occurred on the slope from 2016 to 2017.

3. Overlap analysis of the generated data effectively identified slope displacements and suggested the possibility of using the terrestrial LiDAR for risk slope management.
4. In the future, if periodic data acquisition analysis is performed, it can contribute to improvement of slope stability.

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