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DEM generation of rock slope using laser scanning and digital stereo photogrammetry

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Abstract: There are some reports which are about measuring the discontinuity from 3D model of rock surface. To generate 3D model is mainly based on remote sensing technique like laser scanning and digital stereo photogrammetry. It is obtained the DEM of the rock slope using above techniques in this study, and examined a suitability and improvement of the photogrammetry for the rock slope by overlap the DEM. It seems that accuracy of DEM generated by photogrammetry technique is influenced by the geometry of rock and type of joint.

1. Introduction

It is important to measure the fracture orientation at exposed rock face for the stability analysis. Conventional methods to measure it are using the compass-inclinometer device that is convenient and easy to operate. But operator has to test in physically contact with the rock and it cannot ensure the safety of the operator. Therefore, it is developed that new technique which is like measuring the fracture orientation of the rock slope using 3D model of rock surface generated by laser scanning(Slob et. Al., 2002) and digital stereo photogrammetric technique. It is possible to use digital elevation model (DEM) of stone monuments to test the stability of base rock with safety and to measure the deformed shape by comparing with digital elevation model generated at later time(Baltsavias et. Al., 2001) In this study, attempts were made to generate the digital elevation model of rock slope using laser scaning and digital stereo photogrammetric technique and examine a suitability of the photogrammetry for the rock slope by overlapping the DEM generated by laser scanning.

2. Data Capturing

Target area which had the triangular-shaped wedge failure region was selected. It was applied laser scanning and digital photogremmetry for the target area in due sequence.

Digital photogrammetry

For estimating the accuracy of digital stereo photogrammetry, the stereo image was obtained for the same area where laser scanning was conducted. To decrease the radial distortion which becomes larger and larger where located far from the center of lense, we took stereo images in the position where triangular shape was made at the center of image.

Canon EOS D30 was used with 22.7 × 15.1 mm CCD. The resolution of image was 2,160 × 1,440 pixel and focal length was about 5.6 m.15 targets were attached around the triangular shape of image for the control points and the check points and the 3D coordinate of the points was measured by 5" theodolites DT5S).

To obtain interior and exterior orientation which establishes the position and orientation of the bundle of rays with respect to the object space coordinate system, bundle adjustment was applied (Mikhail et. al., 2001). Table 1 shows the results.

The rectification was conducted before the stereo matching to decrease the parallax which could induce the disparities of the pixels of the same position. Right image is rectified to left image using ERDAS IMAGINE 8.4 and cross correlation method for stereo matching was performed. Then we can get the 3D point cloud pixel using the analytical space intersection with interior, exterior orientations and inverse transformed pixel position.

Table 1. Interior and exterior orientation parameters of reference surface determined by EOS D30 camera (units are radian and mm, respectively).

Camera Parameters	Left	Right
ω	0.227811 rad	0.201134 rad
ϕ	-0.139705 rad	0.205790 rad
κ	0.040883 rad	-0.052426 rad
X_0	-21.581 mm	2068.103 mm
Y_0	1497.158 mm	1704.751 mm
Z_0	8045.914 mm	8019.272 mm
x_0	5.956283 pixel	0.154158 pixel
y_0	-2.359040 pixel	-0.895909 pixel
z_0	27.908419 mm	28.15702227 mm

Table 2. RMSE of 3D ground coordinates of the check points in digital image (units are mm).

	X	Y	Z
RMSE	1.291	1.932	2.468

Laser scanning

Laser scanning was carried out for obtaining DEM from an exposed rock mass. The scans were made with a MENSI S-25 laser scanner which is based on the triangulation technique from two different locations, parallel to the rock face.

The type of data being returned by a laser scanner is a dense point cloud which means 3D position of object. The file (format is *.pts) in X, Y and Z coordinates which are relative to the scanner's position are taked by Rapidform2002 which is software to visualize and to generate DEM with the point data (Figure 3). To avoid the shadow, scanning is conducted from two positions and the two stereo images were obtained. It must be conformed a complete image.

3. Results

Figure 1 illustrates the results of the adoption of two remote sensing techniques. Height difference of both DEMs can be detected by overlapping the DEM from digital stereo photogrammetry on the DEM by laser scanning. The Height of difference between each 3D model from the two methods is shown in Figure 2. DEM by S25 laser scanner is used as the reference data for the analysis of result by digital stereo photogrammetry. S25 ensures an accuracy that is the standard deviation of 0.21mm in 0.8-10m measuring distance.

Dark area means an accordance of the two DSMs. White area is the region where the error is over 74.368 mm. Coefficient of correlation of these regions was represented low value.

It is possible to classify the two regions. One is for the shadows and the other is for the large parallax. The region affected by shadow is arised because the direction and intensity of sun light on getting the left image were different from those on getting the right image. The region affected by parallax is arised because the parallax can be too large at some part. It is possible to see the effect of parallax on the image matching from Table 3

Table 3. Difference of correlation coefficient (r).

Image before geometric correction		Image after geometric correction	
min value	average value	min value	average value
-0.29161	0.409	0.16964	0.720

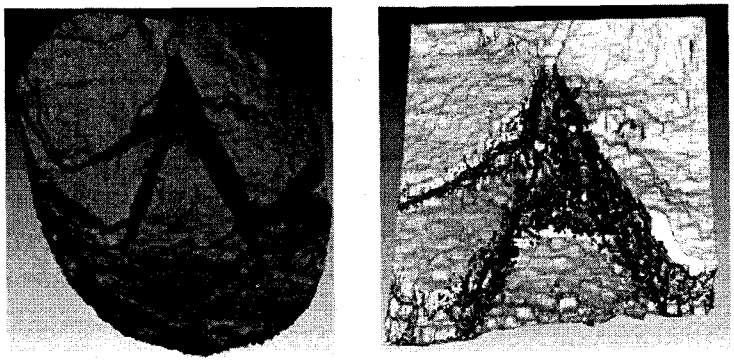

Figure 1. DEM extracted from the data acquired from laser scanning (left) and stereo photogrammetry (right).

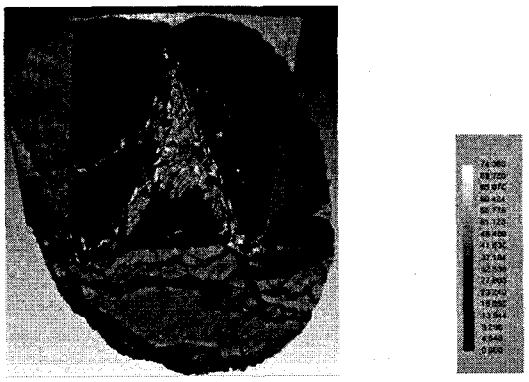

Figure 2. Height differences between laser scanner DEM and photogrammetry DEM (units are mm).

4. Conclusions

The DEMs from digital photogrammetry and laser scanning was compared by overlapping them. To generate the 3D model of rock surface using Digital photogrammetry, effects of shadow and large parallax have to be decreased. It is possible to use the light with stable and strong intensity and direction, and decrease the large parallax at some part. Generated 3D model of natural rock slope is used for the conservation and stability analysis.

References

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