DIGITAL SURFACE MODELING OF JOINTED ROCK IN STONE MONUMENTS USING LASER SCANNER AND DIGITAL CAMERA

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ABSTRACT:

In Korea, there are many stone monuments, such as scarvings on the rock slope. Some of stone scarvings are under severe weathering and others are often jointed, both of which are harmful to the conservation of important stone monuments. Long term conservation of stone scarvings on stone surface requires exact geometry of each jointed rock blocks and then it could be possible to assess the safety and durability of such rock mass on the slope surface. In this study, laser scanning and digital photogrammetry using digital camera were conducted to acquire digital surface model of rock surface.

Comparison of the results with remote sensing techniques shows that data quality strongly depends on the type of each rock and the pattern of joints developed on the rock surface.

1. INTRODUCTION

The conservation of stone monuments like scarvings and paintings on the rock slope is directly implicated in the stability of base rock. So it is important to measure fracture orientation at exposed rock faces for prediction and prevention of deformations.

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. And scarvings or printings on the rock slope can be impaired.

Recently, there was a report on the measurement of the discontinuity from 3D model of rock surface generated by remote sensing techniques such as laser scanning (Slob et. Al., 2002) and digital stereo photogrammetric technique.

Using digital surface model (DSM) of stone monuments has following advantages :

- To test the stability of base rock with safety.
- Not to impair the cultural heritage during the measurment.
- To measure the deformed shape by comparing with digital surface model generated at later time. (Baltsavias et. Al., 2001)
- Usage for the restoration after deformation.
- To re-create 3D virtual cultural heritages model .

In this study, attempts were made to generate the digital surface 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 DSM generated by laser scanning.

This paper is intended to compare the digital photogrammetric technique with laser scanning to generate 3D model of rock. It could be argued what the merits and demerits the method has.

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2. DATA ACQUISITION

Laser scanning and digital stereo photogrammetry are applied the target area in Figure 1. If one uses the traditional approach, as compass-inclinometer device, it seems hard to get the objective result because the test sample is rough and wavy. The site which looks triangular shape was selected. It was characteristic wedge failure region.

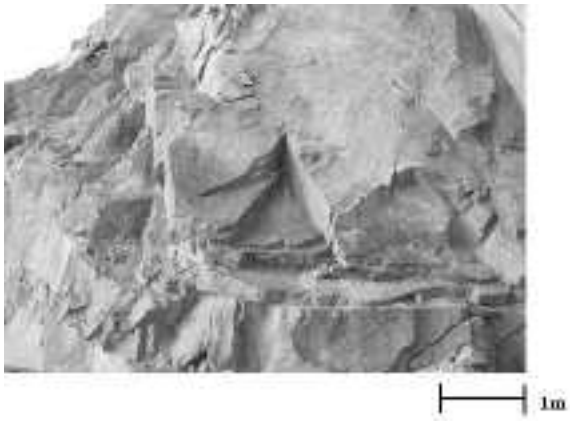

Figure 1. Image of rock face (white circular marks on the rock surface are targets for control)

2.1 Laser Scanning

Laser scanning was carried out for obtaining DSM 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.

Triangulation measurement system works by geometric relation with angle of laser beam, recorded position of laser spot on the CCD and distance of CCD base (Figure 2).

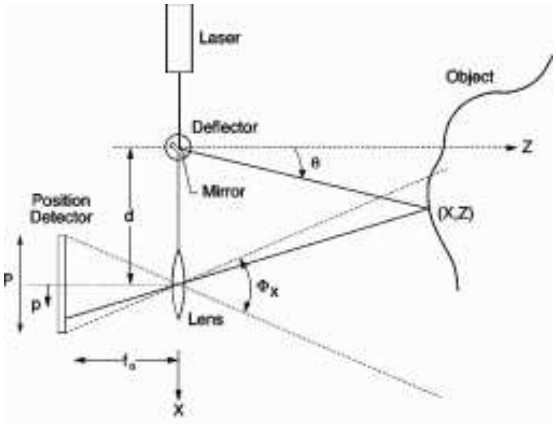

Figure 2. Triangulation methods for range acquisition (Beraldin et. al., 2000)

Triangulation system performs more accurate and fast measurement at moderate range (0.8-10m) and a CCD camera of scanner must detect structured light. Thus the measurement distance was set about 5m and the experiment was conducted under the cloudy sky.

This measurement system consists of computer hardware and software which are for backup the large point data, and laser scanner. 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 DSM 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.

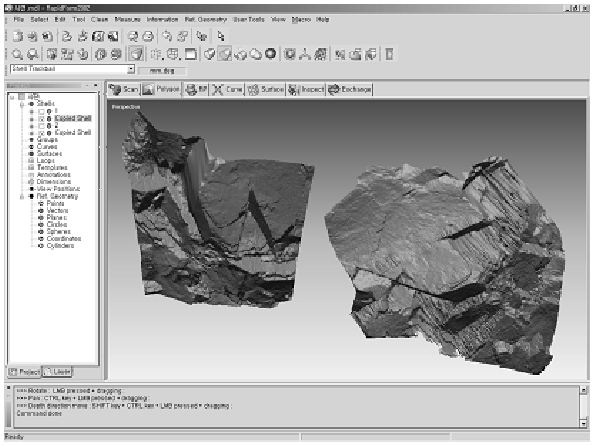

Figure 3. Screen capture from Rapidform2002 program for building digital surface model using the data acquired from laser scanner

2.2 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). Initial position to take the images and targets are shown at Figure 4. The origin was positioned behind the rock face to prevent Z-coordinate being negative number.

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.

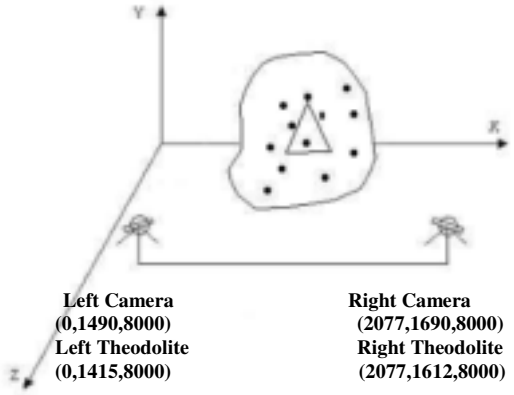

Figure 4. Three dimensional coordinate system : distributed solid circles represent targets (units are mm)

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

	X	Y	Z
RMSE	1.291	1.932	2.468

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

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. Inverse transform equation is following equation :

$$X' = 1.3026\,X + 0.172982\,Y + 54.8103$$
$$Y' = 0.0862574\,X + 1.04515\,Y - 79.7225 \quad (1)$$

where X, Y = rectified pixel position
X', Y' = inverse transformed pixel position

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.

3D model can be generated using Rapidfom2002 (Figure 5.).

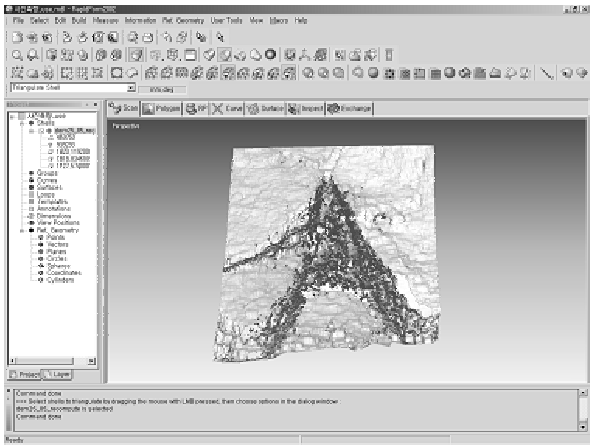

Figure 5. Screen capture from Rapidform2002 program for building the digital elevation model using the data acquired from stereo photogrammetry

3. COMPARISON WITH TWO RESULTS

3.1 3D modeling

It is possible to the difference between the two methods from the results. Figure 6 shows results from each method.

DSM 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.

Heightss of both DSMs can be detected by overlapping the DSM from digital stereo photogrammetry on the DSM by laser scanning (Figure 7.).

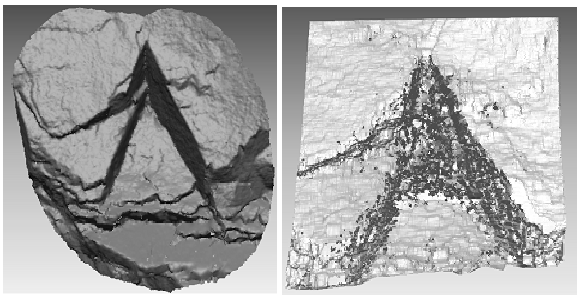

Figure 6. DSM extracted from the data acquired from laser scanning (left) and stereo photogrammetry (right)

3.2 Comparison

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 (Figure 8.). 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 (region B).

The region affected by parallax is arised because the parallax can be too large at some part, like A and B. It is possible to see the effect of parallax on the image matching from Table 3.

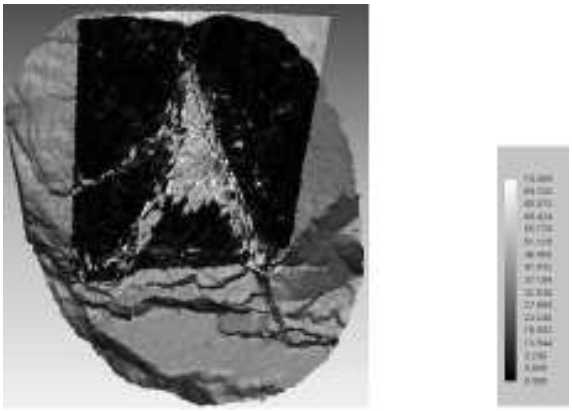

Figure 7. Height differences between laser scanner DSM and photogrammetry DSM (units are mm)

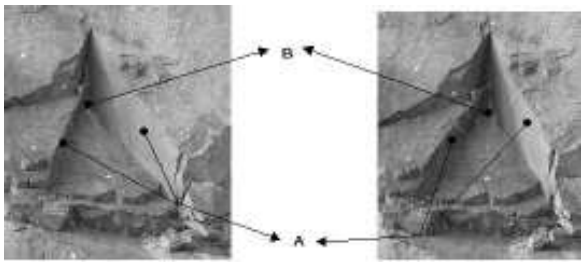

Figure 8. Target region

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

Table 3. Difference of correlation coefficient (r)

4. CONCLUSIONS

The DSMs 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 stone monuments with natural rock slope is used for the conservation and restoration of cultural heritage.

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