

Application of 3D laser scanner for monitoring of landslide hazards

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ABSTRACT:

Landslide hazards are one of the major natural hazards. It is difficult not only to get the integrated and accurate landslide datum but also to monitor and predict the landslide. This paper introduces a ground-based laser scanner application for the landslides monitoring and its experiment in Jingyang, Shaanxi province. The point cloud gained in the test region is processed by existing software, and the result of experiment shows that ground-based laser scanner is effective in monitoring of landslide hazards.

1. INTRODUCTION

Landslide is considered to be a major geologic hazard because it is widely occurred in all over the world, and causes great damages each year. Especially in the residential area, many people are threatened by landslide each year. Landslide and other objects monitoring is one of the study targets in geology, hydrology and geodetic survey. A lot of experiments are applied to monitor landslide in dangerous places. In surveying technique, D-InSAR technique can be used to monitor landslide in a large region. The accuracy of the technique can reach millimeter level in land subsidence monitoring of urban region. D-InSAR technique has been applied to landslide monitoring in Italy, Germany, Austria and so on. Especially in Alpine landslide monitoring, it has got a satisfying result.

For the landslide monitoring of the local region, some other methods are usually used. For example, the monitoring by setup a geodetic deformation monitoring network for side-angle measurement, and by GPS deformation monitoring. These methods are already mature, but only monitor discrete points. They can't offer the integrity of the surface information because lack of enough points. Also they need a great deal of time and high expenditure. Besides, local region can monitored by the close-range photogrammetry, but the accuracy of this technique is lower and it is restricted by the weather condition.

In recent years, ground-based laser scanner is applied more and more widely for landslide monitoring. It can easily acquire large amounts of point cloud in a short time and offer high density and accurate information. It collects data in complex circumstance, scans a series of large, complicated and irregular region quickly, so it can get 3D datum and analyze the status of landslide region by software. 3D laser scanning is a new method of landslide monitoring. It has won a well application in Californian coast slope deformation monitoring of America (Collins B.D., 2004) and Niigata-ken Chuetse earthquake disaster evaluation of Japan in Oct.2004 (Kayen, Robert,2005). A researcher from Toronto University in Canada has contrasted the result by using the total station instrument and ILRIS-3D laser scanner of Optech Company respectively. It shows that the accuracy of single-point positioning is at the same level between two survey methods. In Hoengscong Dam monitoring of Corea and Afternoon Creek rock slide monitoring of

Washington, America, The accuracy reaches 3-7 mm by ILRIS-3D laser scanner (Strouth,2006).

In this paper, there is an example of landslide in Jingyang, Shannxi province. The data is collected by Optech ILRIS-3D laser scanner. The data post processing is done by Polyworks software and Terrascan software. From the analysis above, there is a result of simulative monitoring. The experiment result proves that it is an effective method in landslide monitoring by ground-based 3D laser scanning.

2. EXPERIMENT

2.1. Instrument

In this test, the instrument is ILRIS-3D laser scanner. It is a compact, fully portable and highly integrated package with digital image capture and sophisticated software tools, ideal for the commercial surveying, engineering, mining and industrial market (<http://www.optech.on.ca/ilrisfeatbens.htm>). Its size is similar to a total station. ILRIS-3D has a 6 megapixel digital camera and large screen LCD monitor. It also has high resolution, accuracy and dynamic survey range from 3m to 1500m; the accuracy can reach the level of 3 mm. The basic parameters are shows in Table 1.

Dynamic survey range	3m-1500m
Accuracy	Distance: +/- 7mm Angle: +/- 170 micro-radian
Point resolution	Highest 26 micro-radian
Sampling rate	2000 point/s
Export	Include XYZ point cloud, density, digital image and data explanation.
Operation interface	Digital camera: 4 megapixel Viewfinder: 17cm VGA Controller: Paimtop PDA
Recommended software	Polywork software of InnovMetric company
Size	312×312×205mm
Circumstance temperature	0 - 40 degree/-20-50 degree (placement)
Eye safe	Class I laser rating: completely eye safe

Table 1: Basic parameters of ILRIS-3D

2.2. Test region and test method

There are many mountain massif landslide areas in Jingyang, because of natural disaster or long-term change of circumstance. Some landslides are more than several kilometers long and ten meters height. Figure 1 and Figure 2 are the landslides of this region; Figure 2 shows the ground fissure because of the landslide. If the landslide is near the residential area, more people will be threatened.



Figure 1: The landslide Image



Figure2: Ground fissure because of landslides

In this test, a typical area with 50 meters height and 100 meters long was chosen. It was scanned twice with a fixed station. In the end, it acquired the 3D point cloud and RGB images of the test area. In order to simulate the possibility of the landslide monitoring by this system, a lab assistant is considered as a target on the landslide area. This tested person moved about 1 meter along landslide direction before the second scan. It is a simulated landslide by inspecting the position of tested person. The Basic parameter of the data collection is listed in the table 2. The Figure 3 shows the image of data collection region and the position of the tested person. The yellow circles show the position of the tested person.

Scan distance	100 meter
Horizontal angle	50
Vertical angle	50
Number of shots	5453630
Number of scan lines	1690
Number of points per line	3227
Pulse mode	First Pulse
Scan start position	Lower Left

Scan orientation	Horizontal
X spot spacing(counts/mm)	8/35.2
X spot spacing(counts/mm)	8/35.2

Table 2: The data collection of landslide area in Jingyang

2.3. Purpose of test

There are two purposes in this test. Firstly, it simulates the test area of landslide by the position change of the tested people and gains quantificational result. Secondly, it should filter other objects outside the tested people such as the noise and the vegetation, and then, we can contrast the results of two scans and get the accuracy of the landslide monitoring.

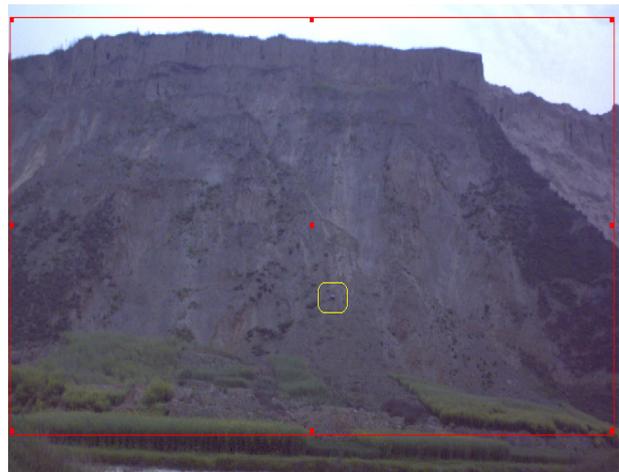


Figure 3: The image of data collection region and the position of the tested person

3. DATA POST PROCESSING AND RESULT

3.1 The results of the data post processing

The original datum should be converted into pif format, this format data can be read by Polyworks. The datum is processed by Polyworks and Terrascan. Terrascan is used to the point cloud filtering here. Polyworks is used to compare to the twi-scanned point cloud and gets the result of landslide.

The datum is processed by some module of Polyworks, Data processing workflow is as follows (Innov Metric Software, 2003):

- 1) Firstly, the collected points should be processed to grid by IAlign module of Polyworks. They didn't need align because of only one fixed station to scan. If the area is large, it should be set several stations from different angle and align all 3D data into unique coordinate system.
- 2) Export pqk format model.
- 3) The point cloud should be compared in Inspect module. The first scanned point cloud are the reference one. The second scanned point cloud are the compared one, which will compare with the first scanned point cloud.

The test result is showed in Figure 4, Figure 5 and Figure 6. Figure 4 shows that the result of overlapping of scanned point cloud. Figure 5 shows the result of visualizing comparison results as colors mapped on the point cloud. Because the

original data points were not filtered and there were some noises on the region of landslide, the result did not obviously show the change. From the Figure 6, the middle of the image is the area of landslide, and there are obvious noises around it. These noises cover the really circumstance of the landslide, so it should be filtered above all.

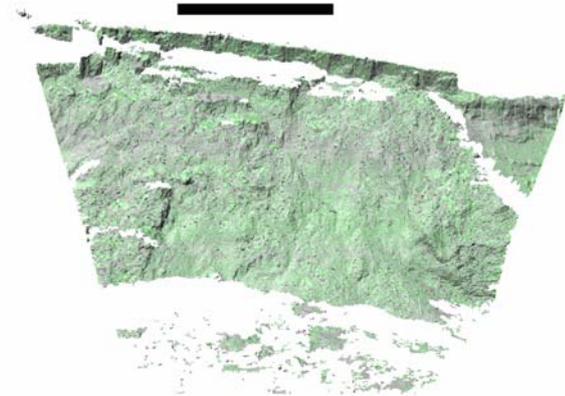


Figure 4: The overlapping of the twi -scanned data points.

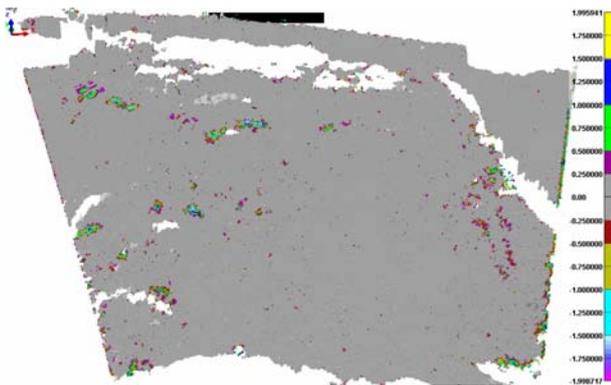


Figure 5: The result of visualizing comparison results as colors mapped.

The point cloud is processed by Terrascan to remove the noises. Terrascan can manage the lidar point cloud. For one thing, it should convert the format of the data to suit the Terrascan software. And then, the noises in point cloud are removed (Terrasolid, 2004). Figure 7 shows the overlapping 3D image of the simulated test of landslide. It can be easily distinguished the change position and the shape of tested person.

After the data processing, noises and vegetation points were filtered. In Inspect module of Polyworks, the point cloud were compared to reference object or other objects in certain direction and inspected the change of position. It can get the direction and grade of the landslide by computing the 3D variety. Figure 8 shows colored vectors attached to an object along the direction of the landslide. According to the fact, it can analyze the certain direction of change state such as X axis, Y axis, Z axis or other direction to specify by yourself. In this test, the tested person moved along the Y axis direction, so the simulated landslide is along the Y axis and the vector direction is Y axis. From the four images of Figure 7 and 8, the test result is that landslide monitoring by ILRIS-3D based-ground

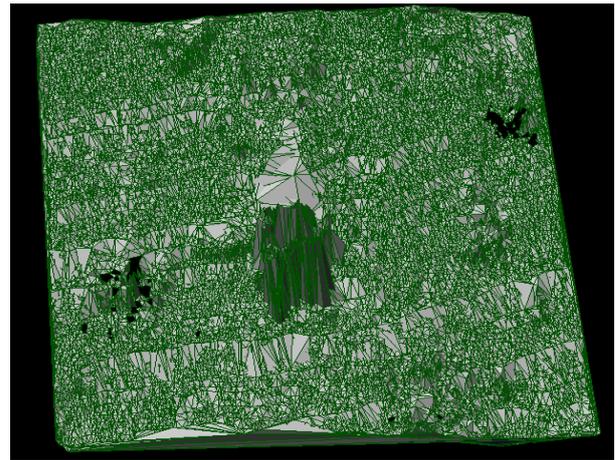


Figure 6: The TIN display of the overlapping twi-scanned data points.

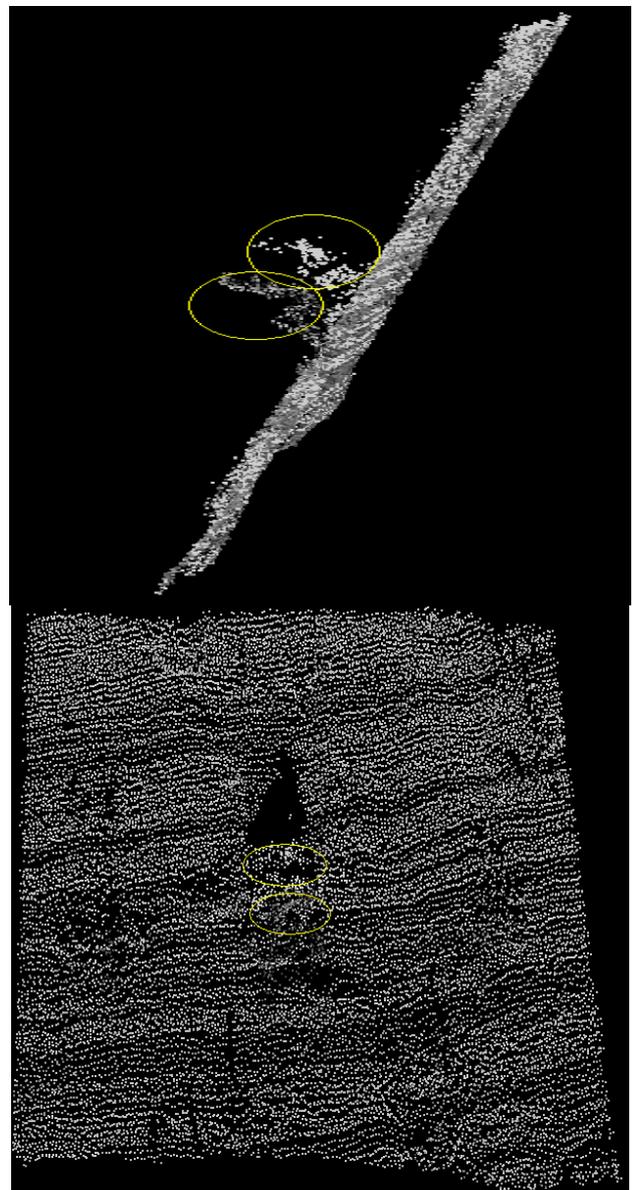


Figure 7: 3D visualizing of data points overlapping (the first is a profile display, the second is a face display)

laser scanner is feasible. The simulated test proves that it can satisfy the needs in large range of the landslide.

Pts within $\pm(2 * \text{StdDev})$	12534 (98.97%)
Pts within $\pm(3 * \text{StdDev})$	12575 (99.29%)

Table 3: the report of the accuracy (Unit: meter)

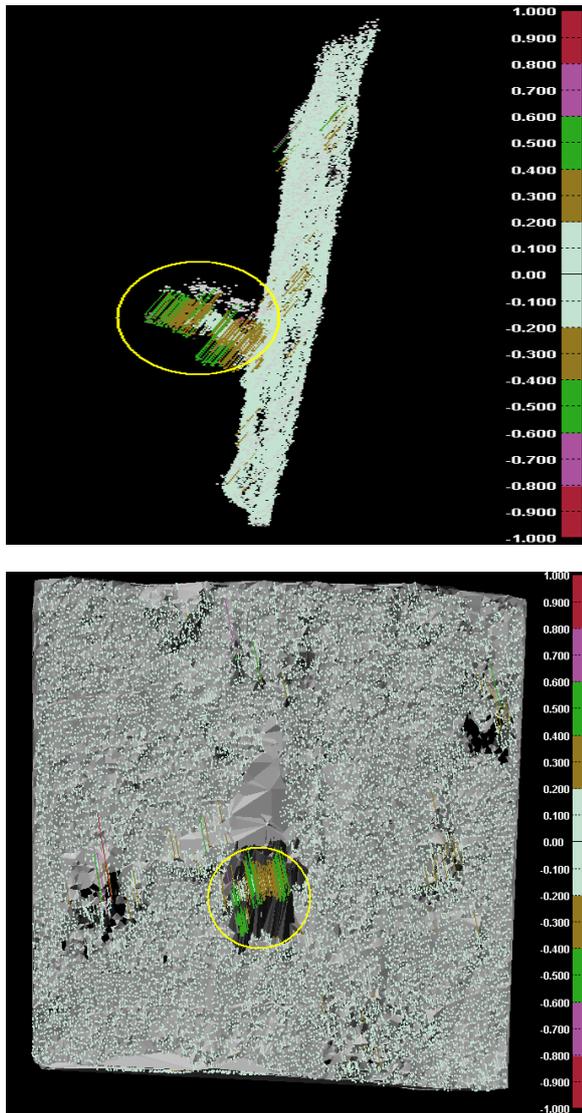


Figure 8: Colored vectors attached to an object along the direction of the landslide (the first is a profile display, the second is a face display)

3.2 The accuracy of the test result

In this test, it not only verifies the feasibility to monitor the landslide but also receives the system errors of ILRIS-3D based-ground laser scanner. The test method is explained in 2.3. The tested person moved about 1 meter along the direction of the landslide in Y axis. It should remove the points of the tested people and filter other noise points. At last, the point cloud is all bare-earth points, and then compare to the tw-scanned datum. The accuracy of the test result is listed in the table3.

Points	12665
Mean	0.001105
StdDev	0.000997
RMS Error	0.000137
Pts within $\pm(1 * \text{StdDev})$	12214 (96.44%)

4. CONCLUSION

According to this experiment, we can draw the following basic conclusion:

- (1) Theoretically, we should carry on the long-term observation to the mountain massif landslides. Then we can analyze the tendency of the mountain massif landslides from these long-term observation data and carry on the effective monitor and the prevention. But the price of this way in the manpower, the physical resource, the financial resource and the time is quite high, therefore, this paper designs this method of simulate mountain massif landslide to carry on the monitor. The test result proves that the way might achieve the quite accurate goal in monitoring the landslides.
- (2) The test result proves that the way of using the ground-based 3D laser scanner to carry on the mountain massif landslide monitoring is effective. In this test method of the paper, we may achieve 3~5 mm precision.
- (3) This way does not need to establish the vast station to observe. By contraries, the methods of the GPS, the geodetic survey or other “point” monitoring need to more station to observe. The method can gain the “surface point cloud” information about the region of the landslide very fast, thus we may monitor the mountain massif landslide effectively and analyze the dynamic change tendency of mountain massif landslide. At the same time, we may return to the original state of these mountain massif surfaces according to “point cloud” data and carry on the 3D surveying on the surface.
- (4) The ground-based 3D laser scanner is a technique of non-contact and active remote sensing. This system can provide the colorful images and deploy by a single operator. The work efficiency is high and the surveyor does not need to arrive at the dangerous region to set up the GPS stations or the prism spots.

5. FORCAST

- (1) This test was only designed one simulated landslide goal. We will consider to setting up more stations in the landslide region in the future, thus we might analyze the landslide fully and effectively.
- (2) Because of the funds and time, this experiment only scanned twice to monitor the simulation landslide. In the future we should carry on the long-term observation in the different stations in order to achieve the goal of dynamic monitoring.
- (3) This system used in the landslide monitor is restricted by the following factors: the available range of system, atmospheric refraction, the reflectivity of the targets and the penetration coefficient of systemic laser and so on. The available range influences the precision, density and reflectivity of the point cloud and so on. If the weather situation is well and the observational distance is not very far, the influence of the atmospheric refraction is not big. The coefficient of main reflection is decided by the type

of the goals, the angle of laser beam and the power of system and so on. The reflectivity is affected severely by the difference of the rock type, the ground soil texture and ground cover. Therefore, it is necessary to choose appropriate season and carries on the full investigation to the soil texture type. The penetrability of laser light is mainly restricted by ground cover and the intensity of laser beam. If the region of the monitoring landslide is not crowded by the massive low vegetations, the influence of the penetration coefficient is not big. If the ground includes the massive low vegetation, we should process the point cloud first.

- (4) The laser scanning cannot instead of the observation completely, because the 3D point cloud could not describe the characteristics of the rock intensity, the soil texture type, the water content and the corrosion. In order to analyze the relations of the landslide with the factors of other types, the field investigation is necessary. But it is still the best method to monitor the landslide in a dangerous region.

In brief, the 3D laser scanner is easily hand carried and deployed by a single operator. In addition, it can obtain the point cloud of the monitoring region fast and effectively. The test result is satisfying. It has the infinite potential in various distortion monitoring.

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