

# DEFORMATION MONITOR BASED ON 3D LASER SCANNER

Zhang Guo-hui

<sup>a</sup>School of Geomatics, Liaoning Technical University, Fuxin 123000, China - zhang\_guohui118@sina.com

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### ABSTRACT:

It introduces the methods of deformation monitoring based on 3D laser scanner. The point clouds obtained by multi-period scanning for deformation monitored object are registered. The coordinate system of point cloud is unified. Constraint stability is tested through two methods. The deformation and trends are analyzed according to the variations of coordinates of center point modeled targets and the difference of object model. The comparison of the multi-period models and coordinate depends on the MESH interpolation. The deformation monitoring is effective according to experiments. The methods could be applied in damage estimation, disaster prevention, mining survey, output of coal estimate, etc.

## 1. INTRODUCTION

### 1.1 Motivation

Deformation caused by mining or natural calamity does harm to side slopes, mountain massif and buildings. Deformation monitor is very important.

There are many deformation monitor methods, such as erecting stress, strain and temperature sensors in the objects which are monitored, or transit survey, total station survey and GPS (Globe Positioning System) survey, etc. However, some deformation monitoring methods have faults. Because the number of sensors is small, or the intensity of labour of manual survey is big, the monitoring points are exiguous. It is difficult to represent deformation features. The cost is big, because of expensive GPS antennas, wiring, plenty of expensive prisms. Moreover, it is dangerous and difficult to install prisms and GPS antennas. A new method should be developed to remedy the defect listed above.

### 1.2 Aims

It introduces the problems and solutions on deformation monitoring based on 3D laser scanner. The application of 3D laser scanner to deformation monitoring can remedy the defect of traditional methods. 3D laser scanner can measure coordinates of object surface points. Measurement is changed from single point to multi-point. The rate of coordinate measurement is up to 1000 points per second, and the distance between points is less than 1 mm<sup>[1]</sup>. The measurement is memorized and displayed at point cloud format. The distance and angle can be measured in point cloud. Modeling based on point cloud is easily.

### 1.3 Overview and references to related work

Laser emitted from Cyrax2500 3D laser scanner is reflected by rotation axis orthogonal mirrors to objects. The laser scans from left to right, from top to bottom. Distance between scanner and laser point is measured. Azimuth angles of laser beam in instrument inner coordinate system are measured. The coordinate of laser point is calculated.

The number and location of station are determined according to worksite. Install the target near the scanner and set up 3D laser scanner, then adjust orientation and dip angle. Take photo for object and draw a scan range on the photo. Setup parameter (row number or resolution ratio) and scan. Big or complex object should be scan at multi stations. The two adjacent point clouds must include 4 or more common targets in order that all point clouds are registered into a whole. If the grid coordinates of the targets are known number, all coordinates of points in clouds can be calculated. Cyrax2500 3D laser scanner is controlled by software, whose name is Cyclone, which can register and calculate residual error. Interference point should be rejected. Then modeling, sections graph and contour graph can be drawn. The data can save as files supported by AutoCAD and MicroStation.

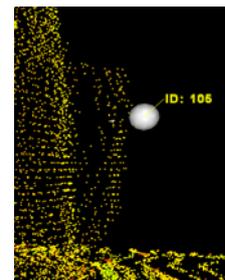


Figure 1. Model of Sphere Target

## 2. THREE-DIMENSIONAL SCANNING DEFORMATION MONITORING SYSTEM

### 2.1 Registration and Coordinate Unification

Size of Monitoring field is in contradiction with distance and angle of view range of scanner. In the scanner range, the scanner leaves a target more near, scan accuracy more high, however, the point cloud size more small, because the limitation of angle of view range. This increases the number of station and increase the amount of work. Moreover, scan station may be influenced by deformation when scanner station is near monitor

object. The 3D laser scanner which has big distance range and large angle of view range is needed.

Some early made 3D laser scanner depends on common targets in adjacent point cloud when it registers multi station point cloud and create a whole point cloud. The common targets are medium of exchange between the scanner coordinate system and local coordinate system. The deformation of common targets must bring about mistake or error on registration and coordinate conversion. The problem of common targets stability is very important.

The stability of common target must be test. The test methods are internal geometric test and external test. The former is by measuring distance and angle between common targets and comparing with other point cloud data. If difference is greater than the threshold, the point stability is open to doubt. Repeatedly assuming and excluding all possibility of doubt, the stability is determined finally. The latter is by survey common target with total station or GPS. Only stable targets are applied to coordinate conversion. Fast scan speed is necessary. Every period scan must be finished in a short time.

Deformation happens as time goes on. An object must be observed continuously or in multi-period. The multi-period point cloud must be analyzed and compared for deformation extraction. Each point in 3D laser scanner's point cloud has coordinate. The coordinate system must be unified for the comparison of two point cloud.

Some early made 3D laser scanners need known target coordinate for coordinate conversion. And coordinate of all targets must be observed by total station, GPS, etc. The coordinate of point cloud must be conversion. It increase not only work burden, but also error and blunder. Some new 3D laser scanners can be operated as total station. It can be located with leveling and orientating. Once the scanner is set up, all coordinate of point cloud will be in grid coordinate system. All the need is measure the station and back sight with total station. The target is not necessary. It is easier for engineers to register all point cloud obtained from different stations. Scan station should be placed in a stable area. After the station, back sight and check points survey, scan the object at once. The coordinate unify is finished at the same time.

## 2.2 Methods of Deformation Extraction

There are two methods to extract deformation. One method is Comparison of Modelled Special Targets. Some sphere targets mounted on deformable bodies are scanned when using the method. The model of the sphere target is analyzed and the centre coordinate of the sphere is extracted. In each period point cloud, a sphere has a unique identifier. The identifier in multi-period point cloud is matched. A sphere's center coordinate in different point cloud are compared. The variation is saved in a file. Then, deformation is indicated. Another Method is difference-modeling, by which method each period point cloud model is compared with the early model. The difference of the models is converted into a file. There are many ways for deformation information to be shown.

The former method is sample test, and the result indicates the local deformation. The validity depends on the location of target. Sphere is shown in Figure 1.

By later method, all points in point cloud are employed in analysis. The resolution ratio of deformation grid is bigger than the former method.

The high and steep slope modeling can be done by Cyclone software's Mesh modeling <sup>[2]</sup> function. Modeling format is Triangulated Irregular Network (TIN) or grid. Digital Terrain Model (DTM) or Digital Elevation Model (DEM) is fit for glaxis.

Because of the difference of MESH (DEM or DTM) which was built from different period point cloud, interpolation for the METH and DEM is necessary. The interpolation for DEM needs resample technique. One resample method is querying the point coordinate in early DEM and calculating appropriate coordinate of point in later DEM. Another method of resample is reconstructing standard grid for all DEM. The standard grid has the same vertex and coordinates increment. Interpolation DEM can be created by calculating weighted mean of adjoining point's coordinates.

Ground deformation was measured adopting traditional techniques and new methods separately. Comparison of results between the traditional and three-dimensional laser scanner indicates that the new methods can tell more details of the deformation and save more time. It gives the solutions for above problems in the paper.

## 2.3 Deformation visualization and prediction

Deformation result (table, text) was visualized in multiple forms: graph, curve, three-dimensional grid, etc. Deformation predicted can be visualized as point cloud and 3D model. The graph of one section deformation is shown in Figure 2.

## 3. CONCLUSIONS

Three-dimensional laser scanner is rapid tool for object surface point coordinate measurement. The appliance of 3D laser scanner to deformation monitoring counteracts traditional technology weaknesses. It relieves labor intensity and enhances the efficiency greatly. The high resolution ratio of 3D laser scanner can bring deformation monitoring enormous convenience and superiority. Through combining the coordinate unifying and modeling technology, the deformation monitoring has been further widened. the data processing time has been shortened.

## REFERENCES

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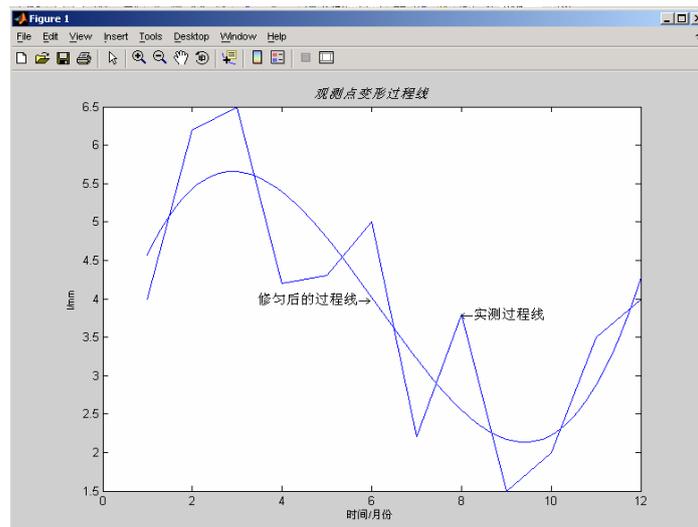


Figure. 2 Deformation graph

