APPLICATION OF POINT CLOUDS FROM TERRESTRIAL 3D LASER SCANNER FOR DEFORMATION MEASUREMENTS

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Commission V: WG V/3

KEY WORDS: Laser Scanning, Laser Scanning Point Cloud, Spatial Modelling, 3D Sensors, Geomorphology, Deformation

ABSTRACT:

3D laser scanning technology has become an exciting and beneficial alternative in the collection of as-built data for plant and facilities applications, where accurate three-dimensional detail of complex facilities is critical for efficient design and construction projects. This paper introduces terrestrial 3D laser scanner as an instrument for two experiments which may be applicable to the field of deformation monitoring. Firstly, results of a Landslide experiment are presented, with Fujiayan Landslide in Wanzhou district in Chongqing as a case study area, investigates the method on high resolution and accuracy DTM generation. Secondly, results of a deformation monitoring experiment are presented. In this instance, a deformation monitoring for the side slope of metro in shenyang within a controlled environment. This forms the basis of a preliminary investigation into the viability of using a laser scanning instrument for deformation measurements.

1. INTRODUCTION

Terrestrial 3D laser scanning is a powerful tool for the surveyor. Like other technological advances in surveying equipment, optimal use of scanning requires the use of "new" information. The EDM introduced the electronically reduced horizontal distance, GPS introduced the "vector" Surveying with a 3D laser scanner generates a new set of information - the point cloud. When compared to traditional methods, point clouds provide a significantly higher level of true geometric completeness and detail of the site - virtually eliminating costly site re-visits to gather more detail or collect omitted features (Charles, 2004).

The laser scanners offer a highly effective method for collecting massive volumes of precise, high-resolution 3D information for deformation monitoring applications. Unlike traditional surveying techniques that collect hundreds of discrete data points over a period of several days, laser imaging is capable of capturing several million 3D points in just a few minutes (Lichti et al., 2000). Multiple station imaging furnishes complete coverage of objects, deforming surfaces (such as pit walls and hazardous slopes), bridges and other structures.

2. THE 3D LASER SCANNING SYSTEM HDS2500

The Leica HDS2500 is a re-branded Cyrax 2500 scanner. The HDS2500 has a maximum 40° x 40° field-of-view and SmartScan Technology™ for added scanning control to let users create highly accurate deliverables while minimizing both field time and office processing time for a wide range of applications & project sites. With a single-point range accuracy of +/- 4mm, angular accuracies of +/- 60 micro - radians, and a beam spot size of only 6mm from 0-50m range, The scanning rate is 1000 points per second. The HDS2500 delivers survey - grade accuracy while providing a versatile platform for data capture. Its 360° x 195° pan & tilt mount and dual internal rotating mirrors enable it to be deployed in virtually any orientation (Cyra, 2003a; Charles, 2004).

The representation of the point cloud is color - coded on the basis of the intensity. It is not uncommon to collect over 1 million points in a single scan, which takes about 10-12 minutes to accomplish. The number of points in a scan is specified by first selecting the area to scan. This is accomplished by using a digital photo image of the scan site, taken by the scanner, and then selecting a "window" of the area using the cursor. After the area is selected, the operator then sets the total number of points, in both the vertical and horizontal (e.g. 200 points vertical X 300 points horizontal). Alternatively, the user can set the specific "point spacing" desired, for example, 0.01ft. Vertical by 0.01ft. horizontal, at a specific range from the scanner. Specific areas that require special detail (e.g. a control target) can be selected and scanned with a higher density of points (Figure 1).
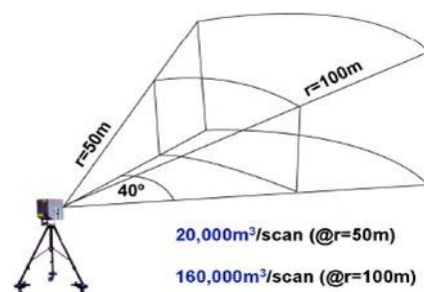

Figure 1. HDS2500 Laser Scanner Field-of-View

The post processing of the data (3D point clouds) was performed with the modular software package Cyclone. The Cyclone software module model controls the scanning parameters during the data acquisition phase and allows the registration of the point clouds as well as the 2D and 3D evaluation. With the COE (Cyra Object Exchange) data format, the loss-free data flow can be carried out to the CAD programs AutoCAD and MicroStation. Using the plug-in CloudWorx for both CAD programs the operator can work on the point clouds using the well-known user interfaces, while millions of points are managed in the background by the Cyclone software (Cyra, 2003b; Charles, 2004).

3. LANDSLIDE MONITORING

3.1 Data Acquisition

During the Scanning of Fujiayan Landslide in Wanzhou district in Chongqing (Figure 2) We have adopt "substation-subscenery" scanning process, The recording of the complete object by the laser scanning system required three different scanner stations, which supplied 42 scans in total using a grid width of 2cm.

Figure 2. Fujiayan Landslide in Wanzhou

For high-accuracy registration every scans, has set up (target plate) two scenery overlapping degree in 30%-50% and 5 target at least. This results in several scan clouds each referenced to a different coordinate system. To be useful, the scan clouds must be registered into a single coordinate system. The process of registration involves identifying common points in each overlapping scan cloud and transforming them into a single coordinate system using a six-parameter, rigid-body transformation. So we measured 7 GPS points for local geodetic network (Figure 3).
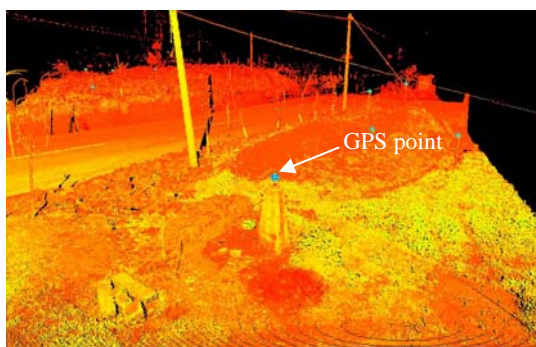

Figure 3. Laser scanner point clouds for GPS reference points

3.2 Point Cloud Processing

3.2.1   Registration: The data processing was carried out exclusively in the Cyclone software modules. The first step of the processing was the transformation of all point clouds from the local scanner coordinate system into the common coordinate system (registration). This processing step was performed in the Cyclone software by a 3D Helmert transformation without a scaling factor (Cyra, 2003b.). A strict adjustment with identical points is not provided in the software.

Three processes are available for the registration of point clouds: Firstly, all point clouds could be registered using only suitable overlap areas with a precision of 2cm; Secondly, the registration can be supported by the use of targets as tie points, which are scanned from different stations (the mean distance to these matched targets (tie points) was 1cm); Finally, the transformation of the point cloud into the local geodetic network could be performed by 7 scanned control points, which were determined with a standard deviation of 2cm using a total station (Figure 4).
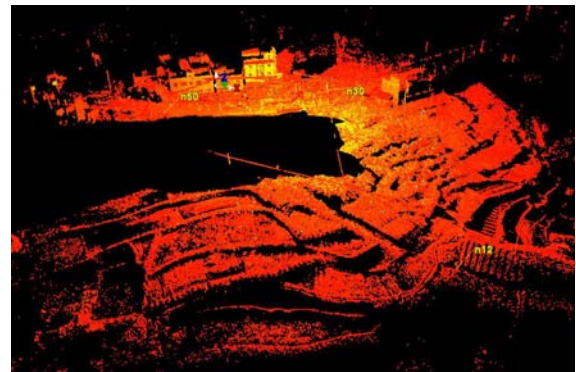

Figure 4. Laser scanner point clouds of Fujiayan Landslide

3.2.2   Removing "Noise" and resample:
Once registration is successfully completed, filtering of the cloud will remove noise from the dataset. Redundant information is also removed at this stage. The data processing of removing "Noise" and resample was also carried out exclusively in the Cyclone software modules.

The first step of the processing was the removing "Noise" of all point clouds. Scanning a site captures everything in the selected field-of-view, including ground points, traffic signs, road surface, telephone poles, fences, etc. Depending on the requested deliverable, these features are highly relevant to the surveyor. However, because the scanner blankets the entire site, undesired objects are also collected, including people, vegetation, trees, traffic, parked cars, etc. As traditional surveys do not typically include such "noise," this is a step in the process that is new to the surveyor. Fortunately, due to recent major advances in point cloud processing software; powerful tools have emerged to allow the surveyor to quickly and easily eliminate noise. An automated process called "region grow" utilizes algorithms that "crawl" across contiguous surfaces to parse out the noise from the surface. In this experiment for example, trees、grass、houses、telegraph pole on a slope may be removed to leave a clear slope for generating DTM later.

The second step was the resample of point clouds. This essentially reduces file sizes and ultimately lowers processing

times for modelling algorithms. In the scanning we used a grid of 2cm for sample. Because of the accuracy was completely satisfied the need of building DTM, We resample point clouds for a grid width of 20cm used the function module called "reduce point cloud".

3.3 DTM

When the preprocessing of point cloud was finished, point clouds can be used as a final deliverable to the client who is taking advantage of cost - effective CloudWorx plug-ins for their existing CAD packages. Earthwork and contouring functions can be performed in the 3D processing software or DTM points can be exported to a 3rd party software for further processing and design. Linework can be generated directly on top of the point cloud and exported to CAD, can be generated in CAD, or can be generated using feature codes and your surveying software's feature code processor. These are just a few examples, in reality, 3D point clouds can be utilized and adapted to most work-flows. Figure 5 shows some examples of field-to-finish work-flows originating with a 3D scan of the site (Charles, 2004).
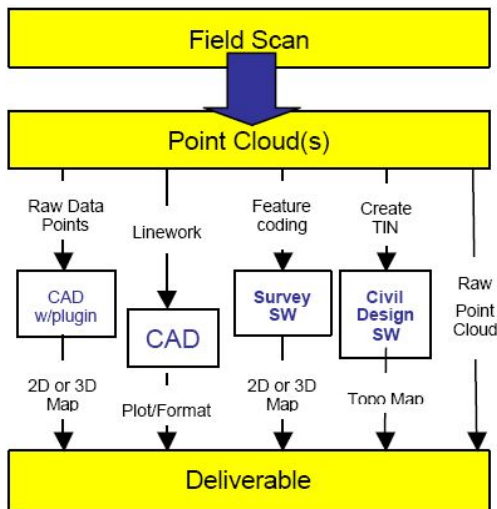

Figure 5. Examples of Work-Flows & Deliverables

In this experiment, point cloud was used for generating DTM of Fujiayan Landslide (Figure 6).
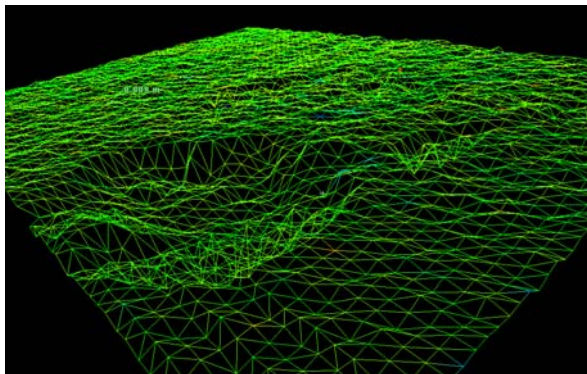

Figure 6. Laser scanner point clouds for DTM

4. DEFORMATION MONITORING FOR THE SIDE SLOPE OF METRO

4.1 Data Acquisition

A deformation monitoring for the side slope of metro in shenyang within a controlled environment (Figure 7). The recording of the point cloud was carried out in the local scanner coordinate systems by 4 scanned GPS control points, The entire side slope of metro could be recorded from 6 stations with 33 scans. The 52 control points was scanned exactly with 2mm spacing for the slope deformation monitoring (Figure 8), The total scanning resolution was in the range of 2cm. The measuring distances to the object were between 15m and 50m.

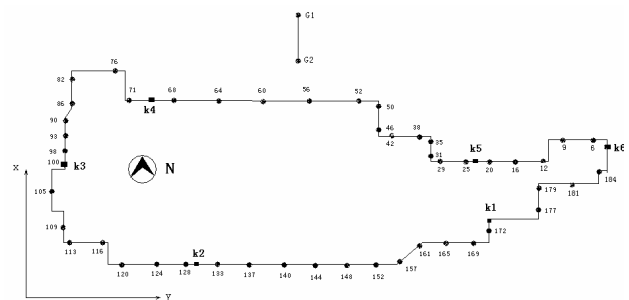Figure 7. The side slope of metro in shenyang

Figure 8. The monitoring points of metro in shenyang

4.2 Point Cloud Processing

The registration of all point clouds (Figure 9) was carried out exclusively using suitable overlap areas in each point cloud. Thereby a precision in the transformation of 2mm could be obtained. The data processing was carried out exclusively in the Cyclone software modules, the data processing by simulation mentioned above.

With 3D laser scanning, there is one major difference in the data collection process: After a scan is completed, feature coding is accomplished in the processing software, not during occupation of each point. There are many advantages to this methodology, including the fact that features are extracted using a mouse click. Feature coding directly inside a point cloud is a revolutionary new way to extract point and line features within the same workflow, as surveyors can use the same exact feature code libraries to identify and label features of significance. Drawing layers, symbols, colors, and other features already configured within the existing feature code

library are maintained. To capture point and line codes efficiently in the desired feature coding format, Cyra's Cyclone software includes a feature called Virtual Surveyor™ that controls the collection of features and ASCII export formats (Charles, 2004). In this experiment, we extracted 52 control points from the registration point cloud used the method mentioned above.
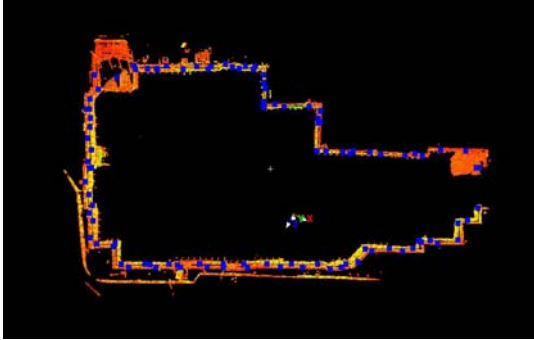

Figure 9. Point clouds of the metro side slope in shenyang

5. RESULT AND OUTLOOK

In conclusion, in two different projects it was demonstrated, that the tested terrestrial laser scanning system is suitable for detailed 3D data acquisition and deformation monitoring. As demonstrated in this paper, it is clear that the 3D laser scanning provides a detailed, reliable, and accurate solution to many surveying and measurement problems. The results of preliminary field testing of a high-resolution laser scanner have been presented with respect to applications in the area of deformation monitoring. A 3D laser scanner generates large amounts of dense information describing a surface. It has been shown that this may be an advantage over traditional methods of surveying, whereby these methods generate discrete points forming a sparse network. In this scenario, local deformations may be overlooked. Furthermore, a laser scanner does not require contact with a surface, whereas traditional methods do. The paper has demonstrated the processes involved with using a laser scanning system.

Due to its measuring accuracy, its high point density, and its measurement speed laser scanning increasingly represents an alternative to and/or an additional option for geodetic and photogrammetric data acquisition methods. In particular, the use of the Cyrax 2500 for the recording of outdoor applications can be recommended although the camera-view scanner has a restricted field of view. In contrast to the outdoor use of the scanner, it would not be very efficient to use the CYRAX scanner for indoor applications because of the narrow field of view.

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