DEFORMATION MONITORING OF DAMS USING LASER SCANNER & OPSIS SOFTWARE

P MEHROTRA
Encardio-rite Electronics (P) Ltd., India

ABSTRACT

The paper describes a relatively new technology of dam deformation monitoring using the point cloud data of the downstream face of a dam collected using a laser scanner and OPSIS software. A laser scanner collects a dense point cloud data of any surface within minutes, getting a detailed description of the object. It had all the features required for fast and contactless deformation monitoring. However, it was not extensively used for the purpose due to three reasons: the high cost of purchasing a laser scanner, the instrument's specified accuracy and difficulties in handling such a large amount of point cloud data. In the last couple of years, laser scanners have become more accurate and affordable. The third obstacle is been overcome by OPSIS, a smart software developed recently. The philosophy behind deformation monitoring is that the forces acting on the dam are causing displacements, mainly perpendicular to the downstream side of the surface, the side we can scan. Monitoring using OPSIS comes down to processing the subsequent point clouds obtained in different epochs and compare with the initial point cloud using the same template and grid. Significant changes will result in variations of the projection cells and make them easily detectable. Animation of the projection's ongoing monitoring and deformation vs time graphs are also presented.

1. INTRODUCTION

The Terrestrial Laser Scanner or LiDAR has been witnessing an increase in its application in the fields of surveying engineering and geomatics as the evolution and improvements in its technology allowed the collection of increasingly more accurate data sets. It has already been widely used for the digitization of the built world, especially for mapping and architectural purposes.

Despite the benefits of LiDAR over the other data collecting methods, such as remarkably higher amount of data collected for the same area in short periods of time without the need to place the targets, and opportunity to tie the measurements to a stable external coordinate frame, the field of Deformation Monitoring was unable to exploit this technology. The reason behind this is none other than the vast amounts of data LiDAR generates, which becomes a disadvantage at the post-processing stage, where the analysis of large data sets acquired at frequent intervals presents a challenge.

2. OPSIS SOFTWARE

OPSIS software has been developed to address the disadvantage mentioned above, overcoming the challenge of processing a large amount of point cloud data in a short period of time. The idea within its core is to perform operations over the raw data from the LiDAR in order to obtain a significantly smaller data set to carry out the analysis. To ensure that the results obtained out of the analysis of this sub-dataset have to be equivalent to those obtained evaluating the original one, the operations involved must ensure to preserve the spatial information contained within the input data.

2.1 Design philosophy

LiDAR provides us with multidimensional spatial information in the form of point clouds. After going through a filtering process to eliminate the noise, the first calculation performed is the projection of each point of the said cloud over a mathematically defined surface. Determination of the type of surface is done on the basis of best-fit adjustment to the specific point cloud. From this moment on, we have the ability to display the three-dimensional data on a two-dimensional representation, although the volume of data we have to work with remains the same, as we still gather the same number of points defined by 3 parameters (coordinates on the projection surface and distance). To resolve the obstacle presented by the extensive amount of data, the second transformation of the data is performed. Said transformation is the tessellation of the 2D representation using a squared grid of adjustable size. The points contained in each cell are the subject of a statistical analysis focused on the distance from each point to the surface, obtaining a mean deviation value for each grid's cell. Setting a maximum deviation value, the cells are classified into two categories, accepted and rejected. The values of those accepted cells are the subject of the deformation analysis, thus achieving the goal of obtaining a reduced data set to analyze.

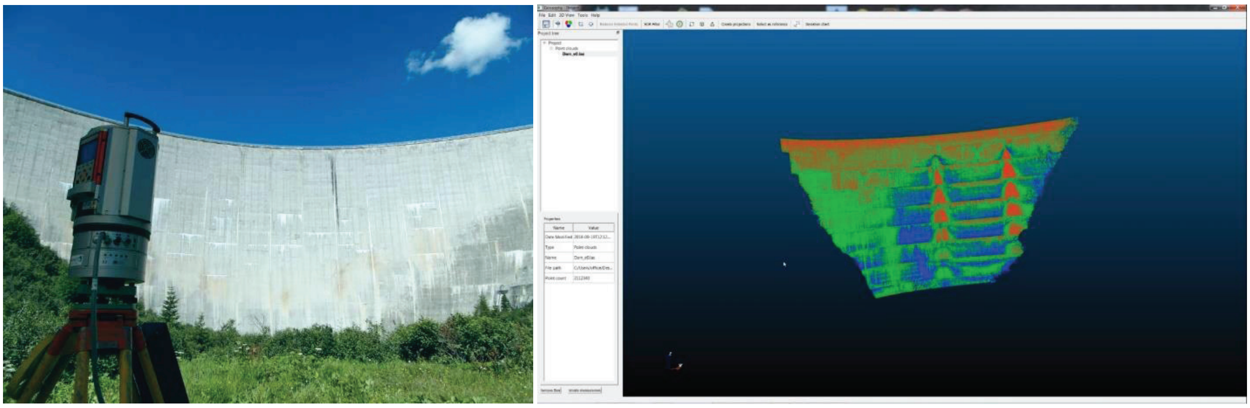

Figure 1 : Dam deformation monitoring using a laser scanner and OPSIS software

2.2 Suitability for Deformation Monitoring

The task of monitoring the deformations or displacements of the scanned objects (Figure 1) to perceive possible changes using this software comes down to processing the subsequent point clouds obtained in different epochs using the same projection surface and grid obtained as the best fit for the initial point cloud (Figure 2). If significant changes in the object's geometrical form were to occur, variations of the cell's mean values will make them easily detectable.

What differentiating OPSIS from the existing similar software suits, that it does not just compare the point cloud pairs, it also generates a linear diagram visualization of the deformation history of each grid cell (Figure 3). The above makes it a great tool for the deformation analysis of dams in conjunction with a suitable laser scanner.

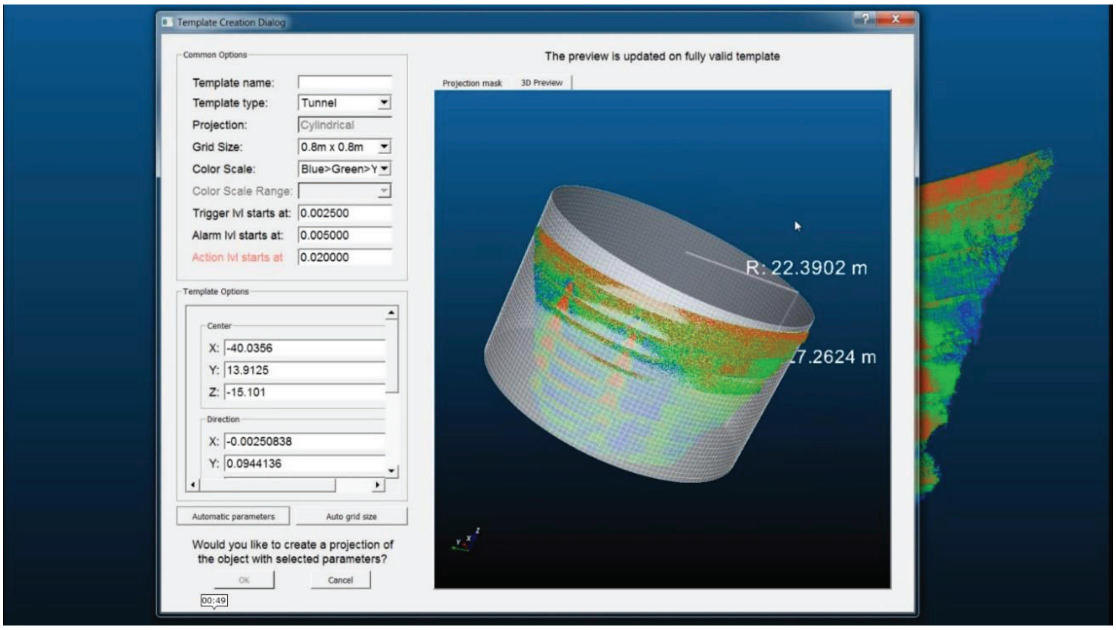

Figure 2 : Project template creation in OPSIS

2.3 Features

Other features of the OPSIS software apart from the ones described above are as follows:

- Limitless point cloud comparison
- Full surface deformation maps
- Time-lapse animation of the deformation maps
- Custom color scales
- Scalable graphs
- Custom alert alarm and action levels per template
- Customization of the projection mathematical template and results grid
- Imports .las, .pts, .e57, .ply, .xyz files
- Exports in pdf, xml and csv formats

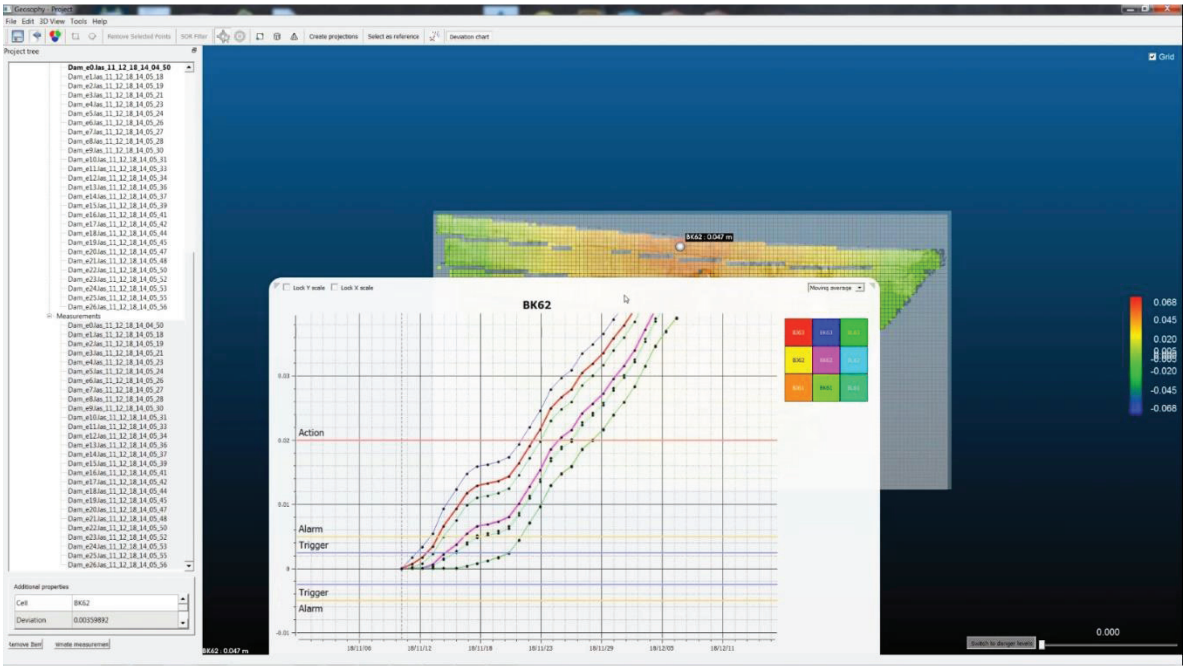

Figure 3 : Deformation graph creation in OPSIS

2.4 Advantages

- Covers the dam's surface fully thus allowing monitoring in between other installed sensors
- Allows measurements without jeopardizing the safety of personnel to install and maintain prisms at difficult to reach and risky locations on the dam. In the arch dams due to the inwards curvature, installation and maintenance of the prisms are especially difficult. It also cuts down the time to apply for the work permits, NOC etc. to install the targets
- No conflicts with the construction progress
- The measurements are contactless eliminating chances of mishaps due to site construction activities, vehicular traffic, etc.
- Allows fast processing of dense point cloud data resulting in a quick report generation for in-tile assessment of the situation and planning corrective measures, if any
- Allows focusing on the problematic area instantly
- Helps in optimizing the monitoring documentation

3. CONCLUSION

OPSIS software helps in harnessing the power of LiDAR for deformation monitoring of large dams. The above combination provides s cost-effective and efficient means of deformation monitoring resulting in data that is both easy to visualize and customize. The data, when analyzed with that gathered from other conventional geotechnical and environmental sensors installed in the dam gives a complete picture of the health of the dam to the stockholders and O&M teams. Thus, allowing timely actions in case of any unexpected performance of the dam.

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