

A METHOD FOR EXTRACTING DEFORMATION FEATURES FROM TERRESTRIAL LASER SCANNER 3D POINT CLOUDS DATA IN RGIPT BUILDING

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ABSTRACT:

With the advancement of measuring technology and the incorporation of photogrammetry into architectural applications, architectural documentation applications have taken on a new viewpoint. Terrestrial laser scanning is a modern approach employed in documentation research today in this field. The following are the most significant advantages of terrestrial laser scanning in this study. The point cloud data obtained by terrestrial laser scanners (TLS) allows for quick access to the correct data at the specified frequency, generating relevant and practical findings for the targeted study, and the ability to use scanners in a variety of working environments. Laser scanners have become one of the most popular tools for obtaining effective and successful outcomes in architectural documentation projects such as surveys, restitution, and renovation. Standardized building rules and design procedures have been developed to create structures that are safe for public usage. Structures are frequently subjected to severe loading situations and difficult environmental situations that were not anticipated during design, resulting in a long-term structural deformation. In this paper, the “RGIPT”, which is one of the educational institutes in Uttar Pradesh, India, was scanned with a terrestrial laser scanner for this study, and 3D sketching, and modelling were done with the SCENE software utilizing only 3D point cloud data. Few columns of the structure have been considered for this paper and their behavior with vibration loading is observed. To conduct this study variation of variances for X-direction and Y-direction is observed for millions of points with increasing height of the structure to predict the upcoming deformation in studied columns of the structure.

1. INTRODUCTION

Structural Health Monitoring (SHM) is aided by Terrestrial LiDAR or Terrestrial Laser Scanner (TLS), which is used to identify structure displacement, strain, distress, surface crack, corrosion, and collision damage, as well as critical structural factors like bridge clearance, degree of curve, and skew distance. Lower clearance bridges are more vulnerable to vehicle collisions and damage. Vertical structural movement, pavement overlays, or ground subsidence can all cause changes in clearance height over time. Bridge inspection should be done on a regular basis to avoid bridge collapses and structural failures, which are becoming more common. Vehicle-mounted laser scanning technologies have been proven to drastically cut bridge inspection time. It may be used to visualize and evaluate bridges, dams, and other big structures in a 3D environment, and it can also be used to monitor structural health. TLS was utilized to collect 3D data about a dug tunnel at various points in time, and it was discovered to be a promising technique for tunnel applications. TLS can also be used for digital documentation of cultural heritage and landmark constructions.

LiDAR is a new technology with a lot of potential in the civil and construction engineering fields. It has a cm level of accuracy in both vertical and horizontal directions, thus it may be used for everything from precise topographic surveys to geotechnical, coastal, transportation, structural engineering, 3D modelling, and planning (Sowmya & Trinder, 2000). LiDAR surveys give precise elevation data, which can be utilized for water resource monitoring, computation of cut and fill volumes, and thorough road and building surveys (Carleer et al., 2005). Over the last decade, three-dimensional modelling of built buildings has gained popularity and has been used for a variety of purposes, including urban planning, visualization and navigation of built things, computer gaming, virtual tourism, real-time emergency

response, and more (Sun et al., 2020). For producing 3D models, there are a variety of open source and commercial software options available, such as Google SketchUp and others. Even model of a single structure, however, necessitated a significant amount of human effort. When comparing the extracted building heights to photogrammetric heights, the extracted building heights were determined to be more accurate. As a result, TLS data is ideal for a broad range of 3D modelling purposes (Biswas & Lohani, n.d.). In current years, 3D surface modelling, Virtual reality, decision analysis, and computer-assisted design have all benefited from this technology, which is based on surface point clouds of 3D entities and is automated and computer-assisted (Dubey et al., 2021). And point cloud sources, such as air-borne and terrestrial mobile laser scanner data, indicate a tendency of diversification. The objects of modelling in the fields of surveying, urban planning, and urban 3D landscape modelling are typically buildings, which have a large number of planar surfaces (Dong & Catbas, 2020). As a result, the research of obtaining building features, particularly plane features, using the information retrieved from the related point clouds is viable (Dung & Anh, 2019). The following are the primary properties of these modelling targets:

Many consistently plane surfaces or near plane surfaces are present in the item, such as in complex polyhedrons. Only a few curved surfaces may be present on the object.

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2. LITERATURE REVIEW

2.1 LIDAR in Civil Engineering

Light Detection and Ranging (LiDAR) is an active optical distant sensing device that can be either airborne (Airborne Laser Scanning) or ground-based (Terrestrial and Mobile Laser Scanning) and mounted on a tripod or vehicle (Sharma and Biswas 2020). It does not rely on the Sun to illuminate the target; instead, it creates its own laser pulses that impact the object and are reflected. It calculates the time taken by the laser pulse to determine the distance between the sensor and the item (i.e., from the release of laser pulse to receiving back the laser pulse). Due to partial reflection from various objects, each laser pulse can yield many returns. For example, a component of a laser pulse reaching a tree's top is reflected initially (1st return), then the remaining section of the pulse travels lower down and may be reflected back by branches (2nd return), and the final part of the pulse may hit the trunk/ground and return back (3rd return). The strength of the return pulse is usually used to determine whether or not a particular return pulse is useful (Bharadwaj et al., 2022). LiDAR works in the optical region of the Electro-Magnetic Spectrum (EMS) (Blue-Green/Near Infrared), whereas RADAR works in the microwave region. For precise land surface measuring, topographic LiDAR operates in the EMS NIR range (900–1064 nanometers). Due to its water penetration capabilities, bathymetric LiDAR in the Blue-Green region of EMS is utilized to obtain topography above and below the water surface. The standard LiDAR data comprises of a large number of points (referred to as a point-cloud) with exact xyz measurements, as well as information on the ground reflected laser pulses (Sester & Neidhart, 2008). Because it is an active remote sensing technology, it can also be used at night. LiDAR is a new technology with a lot of potential in the civil and construction engineering fields. It has a cm level of accuracy in both vertical and horizontal directions, thus it may be used for everything from precise topographic surveys to geotechnical, coastal, transportation, structural engineering, 3D modelling, and planning. LiDAR surveys give precise elevation data, which can be utilized for water resource monitoring, computation of cut and fill volumes, and thorough road and building surveys (Zhang et al., 2019). The standard LiDAR data comprises of a large number of points (referred to as a point-cloud) with exact xyz measurements, as well as information on the ground reflected laser pulses (Sester & Neidhart, 2008). Because it is an active remote sensing technology, it can also be used at night. LiDAR is a new technology with a lot of potential in the civil and construction engineering fields. It has a cm level of accuracy in both vertical and horizontal directions, thus it may be used for everything from precise topographic surveys to geotechnical, coastal, transportation, structural engineering, 3D modelling, and planning (Sotoodeh, n.d.). LiDAR surveys give precise elevation data, which can be utilized for water resource monitoring, computation of cut and fill volumes, and thorough road and building surveys (Park et al., 2007). The following are the primary properties of these modelling targets:

- Many consistently plane surfaces or near plane surfaces are present in the item, such as in complex polyhedrons.
- Only a few curved surfaces may be present on the object.
- An approximate right angle exists between the normal lines of two adjacent surfaces.

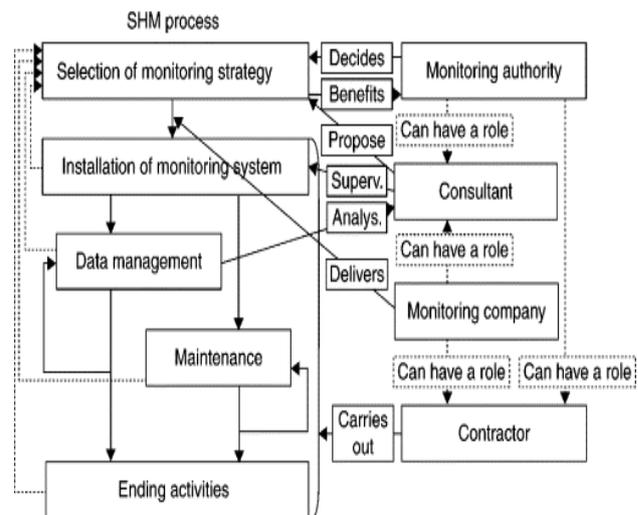


Figure 1. Flow chart for structural health monitoring

2.2 Building Extraction Process from Remote Sensing Data

LiDAR data delivers a high-precision Digital Elevation Model (DEM) and micro-topography (Fraser & Riedel, 2000). The data can even penetrate below the tree canopy, revealing the tree structure and surface value. It can also be efficiently processed to obtain the Bare Earth Model (terrain model). Flood modelling, watershed and stream delineation, landslides and slope stability analysis, cut and fill analysis, tsunami inundation modelling and shoreline mapping, infrastructure planning and monitoring, integrated storm water management plan, geomorphological studies, road and rail route alignment, site planning, and many other applications have all benefited from LiDAR's high resolution surface model (Liu et al., 2011). Planners and engineers can build different scenarios at the planning and design stage thanks to the high-quality DEM and GIS (Bharadwaj et al., 2020). Figure 2 gives the briefly idea about the extraction process for structural health monitoring.

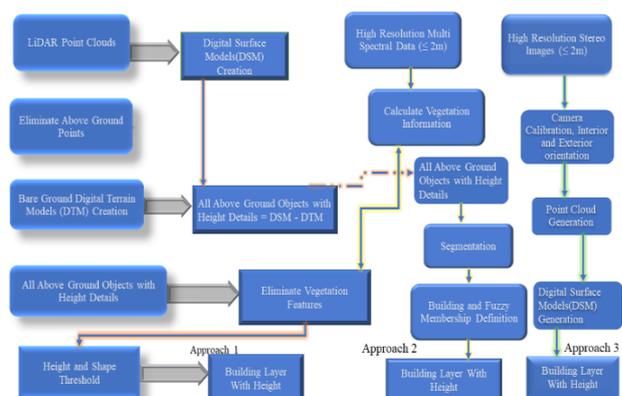


Figure 2. Extraction Process for structural health monitoring

3. OBJECTIVES

The authors of this paper attempted to find out strategies for measuring the deformation of constructing RGIPT regions in a low-cost and convenient manner. The authors will try to figure out how to do it.

1. Use of terrestrial laser scanner(TLS) for collecting 3D point cloud data .
2. Use of SCENE software for point cloud data processing.
3. Use of SAP2000. Software for Deformation analysis.
- 4.

4. METHODOLOGY

The authors have chosen RGIPT Building for extraction of 3D point cloud data for deformation analysis or structural health monitoring.

4.1 Filtering

Filtering is a pre-processing procedure that distinguishes ground points from non-ground points, lowering data size and assisting with building point identification. The filtering algorithm used falls within the surface-based filtering group. The distance to the mean interpolated surface was used to provide a weight to each location. The distance between each point and the mean surface was used to define a threshold. The points are classed as ground or non-ground based on the threshold value(Olsen et al., 2009). The filters compare the scan point to the scan points in the surrounding area in order to identify an incorrect scan point. Some of them are filtering is performed based on information from the point(Park et al., 2007). The surrounding region is directed towards the scanning process, that is, it is orientated toward the rows and columns, as seen in the Planar View.

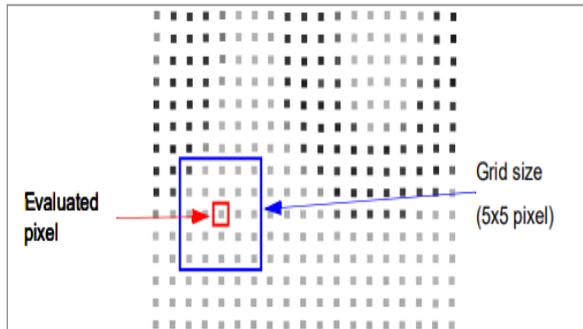


Figure 3. The area surrounding a scan point, in a 2D grid

In figure The surrounding area is depicted with the recording location in the centre. The scan points within the surrounding square are in close proximity to the single scan point highlighted. You can define what should be considered the surrounding area by using filters. The value 5 was used in this example, indicating that the surrounding square's edge length is 5.

4.2 Dark Scan Point Filter

The Dark Scan Point Filter removes points based on a reflectance value. Reflectance Threshold: indicates the minimum reflectance value a scan point must have. The Reflectance Threshold range is: 0 to 2048. Because just a little amount of light penetrated the scanner at a dark scan spot, the measurement will have more noise.

4.3 Distance Filter

The Distance Filter simply removes all scan points that are outside of a specified range of distance. All points with a distance less than the Minimum Distance will be deleted, as well as all points that have a larger distance than the Maximum Distance.

4.4 Stray Point Filter

The Stray Point Filter checks if the 2D grid cell of a scan point contains a sufficient percentage of points with a distance similar to the scan point itself.

4.5 Grid Size

For comparison, the size of the surrounding area was used. The filter counts how many valid scan points in this surrounding area are at a distance to the scanner that is about the same as the distance of the scan point now being examined for each scan point.

4.6 Distance Threshold

If the difference in distance is less than the Distance Threshold, a scan point is counted.

4.7 Allocation Threshold

The scan point remains in the scan if at least the proportion of scan points given by the Allocation Threshold in the surrounding area is likewise within this distance threshold. Otherwise, it will be taken away.t of the scan or selection.

4.8 Terrestrial Laser Scanner Method

With the use of LiDAR technology, terrestrial laser scanning technology samples or scans objects immediately, precisely, and automatically, getting 3D coordinates (x, y, z) (Priestnall et al., n.d.). It is based on a technology that scans the target item in a sequence of points at limited angles in both horizontal and vertical dimensions, allowing point clouds to be presented(Rehor, 2007). The time it takes for the LiDAR signal to hit the object and the reflected beam from the target back to the scanner determines the location of a point(Rehor & Voegtle, n.d.). As a result of these actions, scanner centered polar coordinates are acquired. The cartesian coordinates are converted from the polar coordinates

5. COMPUTATION

5.1 Time-of-Flight Scanners

Three-dimensional laser scanners typically use two different kinds of distance measurements. The distance module of the FARO Laser Scanner Focus uses the "Phase Shift measurement". Other systems use the "Time of Flight Measurement" to measure long-range distances. Time-of-flight scanners measure the amount of time it takes for the emitted laser light to return to the scanner and use that time to calculate distance.figure 4. shown the working principle of time of flight measurements.

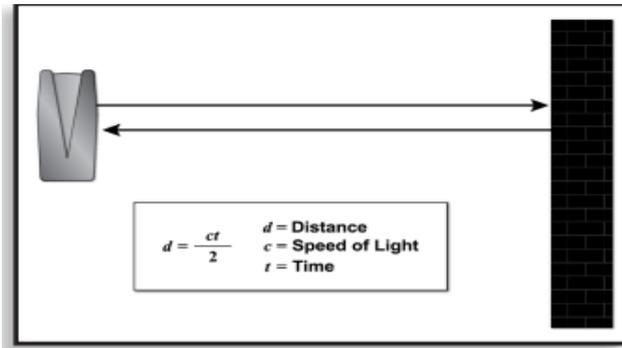


Figure 4. The working principle of time-of-flight measurements

5.2 Phase-based Scanners

The Focus uses phase-based time of flight measurement. All time-of-flight scanners emit laser light and measure the time until it is reflected back to the scanner and received. Phase-based scanners modulate the amplitude of the emitted laser in sine-wave-like patterns. When the laser light is reflected by the object and received by the scanner, the waves seem to be delayed or shifted versus the waves that are currently emitted. This shift is the basis for the distance measurement; it is directly proportional to the distance of the object.

The x, y, z coordinates of each point are then computed by measuring the mirror rotation and horizontal rotation of the Focus with angle encoders. These angles are encoded at the same time that the distance is measured. A polar coordinate (r, ϕ, Θ) is made up of distance, vertical angle, and horizontal angle, and it is then translated into a Cartesian coordinate (x, y, z) . TLS operates on a tripod or on a mobile mapping system. Instead of one direction scanner TLS have panoramic and spherical direction. Phase management has a higher data rate and better accuracy (1-3 mm) but for shorter range (20 – 80 mm). TLS contains an integrated camera to color the point cloud.

SAP2000 provides an interface to design a structure with appropriate loading. Firstly we define the material used in structure and correspondingly structural members are defined. Load pattern and various combinations of loads provide an accurate result for designed structures. The deformations in structure mainly depend on the period of oscillation due to running train on the track. This scenario in this study is created considering a seismic study with very low value 1.5 kN of quake load and corresponding change is observed for increasing value this load until deformation of the structure is obtained. Since the considered structure is reinforced concrete structure. So the total time of oscillation is calculated using the relation from IS code 1893: 2002

$$\frac{0.075h^{0.75}}{\sqrt{A_w}} \geq \frac{0.09h}{\sqrt{d}}$$

Where A_w is total effective area of walls in the first story the building.

h = Total height of the building

d = base dimension of the building at the plinth level.

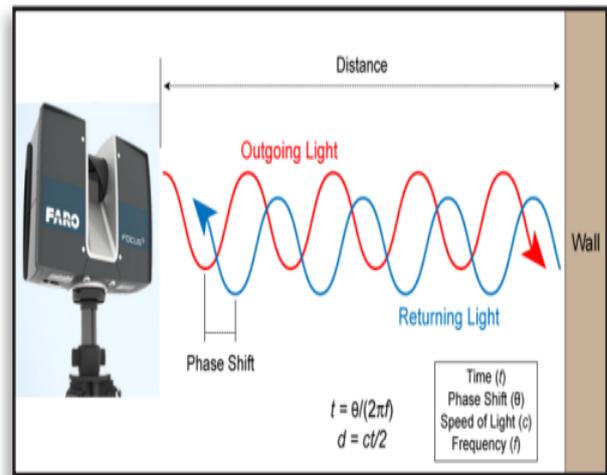


Figure 5(a). The working principle of Phase-based measurement.

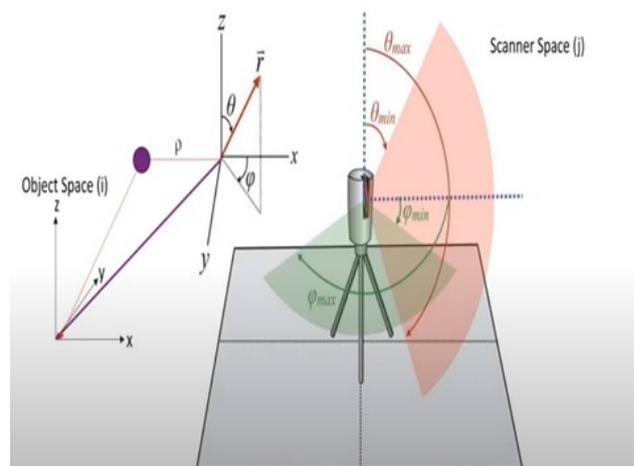


Figure 5(b). The working principle of Phase-based measurement.

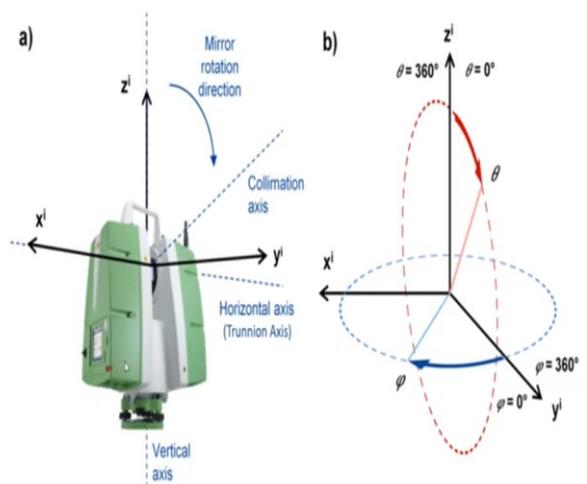


Figure 6. Terrestrial Laser Scanning Axes with their respective angles.

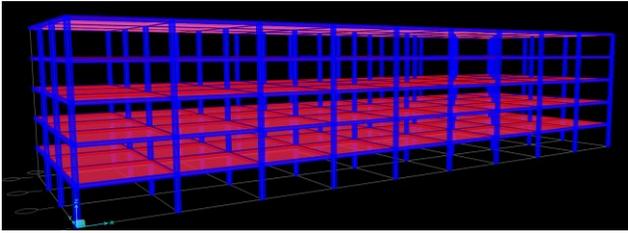


Figure 7. Layout of Academic building 2.



Figure 8. 3D point cloud RGIPT process data by SCENE software.

6. RESULTS

In this basically, Base shear V_B along any principal direction is determined by

$$V_B = A_h * W$$

A_h = design horizontal acceleration coefficient value.

W = total seismic weight of the building as per IS code 1893:2002.

Deformation of Reinforced concrete buildings are obtained using structural model after analyzing the structure based on section properties. Deformation can be seen in structure after analysis and its values are obtained in tabular form with the help of SAP2000. Figure. 9 and figure. 10 shows the deformation layout respectively.

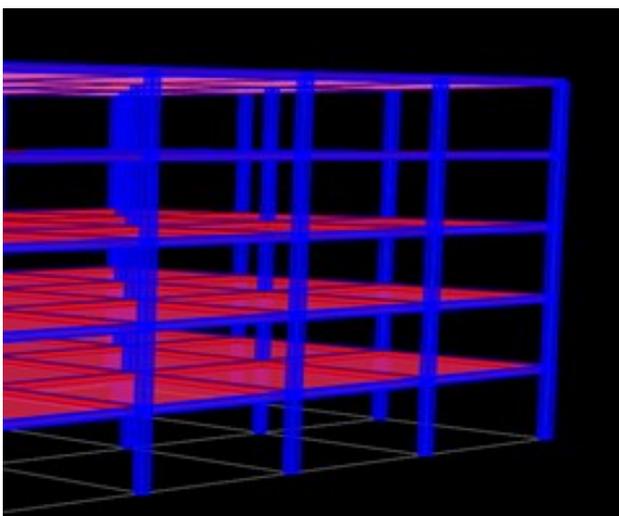


Figure 9. Layout without deformation

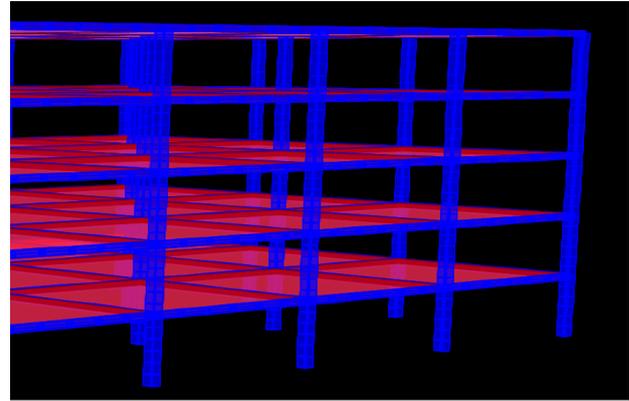


Figure 10. Layout with deformation



Figure 11. 3D point cloud RGIPT Academic building 2 process data by SCENE software

From the above result author can say this study variation of variances in column for X-direction is 14 mm and Y-direction is 20 mm observed for millions of points with increasing height of the structure to predict the upcoming deformation in studied columns of the structure.

7. CONCLUSION

The authors examined the work of a number of structural health monitoring researchers. A Terrestrial laser scanner and data processing using SCENE software were used to tackle the difficulty of 3D point cloud data for huge structures. With the help of IS code 1893:2002, the authors attempted to estimate the deformation using SAP2000 software. The method consisted of two parts: easy and effective deformation extraction and SCENE software's creation of a 3D map of the rgipt building.

8. FUTURE WORK

Because each building's islet is constrained by its georeferenced trajectory, future research could look at expanding the approach to buildings with more complex geometries and applying it to larger areas. Furthermore, because cars cannot access outside squares inside structures, we plan to expand our approach to depict entire buildings by combining terrestrial and aerial data..

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