# Automatic identification of deformations in buildings and pipelines using 3D point cloud data for Structural Health Monitoring

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## Abstract:

With the advancement of measuring technology and the incorporation of photogrammetry into civil and oil & gas infrastructure health monitoring 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 thesis`, 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, beam and pipelines of the structure have been considered for this thesis 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 column, beam and pipelines of the structure.

**Chapter 1:** The SHM is offering a strategy for debacle control of largescale structures. This strategy is better than the conventional break source impediment method. Right now, specialists have attempted to take a shot at novel, vibration-based condition evaluation strategies, and electro-mechanical impedance techniques (EMIT). It is understood that these noticeable strategies give points of interest for evaluating the exact weaknesses of largescale common foundations. Also, the assessment examples and their status of examinations are being researched. The work will direct the specialists working in SHM on utilization of newer innovations for far reaching assessment of fracture of structure.

**Chapter 2:** Regular monitoring of the health of industrial equipment is necessary, and thus, the concept of structural health monitoring (SHM) comes into play. In this chapter, the purpose is to highlight the importance of SHM systems and various techniques primarily used in pipelining industries. There have been several advancements in SHM systems over the years such as Point OFS (optical fiber sensor) for Corrosion, Distributed OFS for physical and chemical sensing, etc. However, these advanced SHM technologies are at their nascent stages of development, and thus, there are several challenges that exist in the industries. The techniques based on acoustic, UAVs (Unmanned Aerial Vehicles), etc. bring in various challenges, as it becomes daunting to monitor the deformations from both sides by employing only one technique. To determine the damage well in advance, it is necessary that the sensor is positioned inside the pipes and gives the operators enough time to carry out the troubleshooting.

**Chapter 3:** Real-time health monitoring of civil infrastructures is performed to maintain their structural integrity, sustainability, and serviceability for a longer time. With smart electronics and packaging technology, large amounts of complex monitoring data are generated, requiring sophisticated artificial intelligence (AI) techniques for their processing. In this chapter, a comprehensive review is performed, primarily on the applications of AI models for SHM to maintain the sustainability of diverse civil infrastructures. Three smart data capturing methods of SHM, namely, camera-based, smartphone-based, and unmanned aerial vehicle (UAV)-based methods, are also discussed. The integration of SHM with IoT and cloud-based computing is leading us towards the evolution of future smart cities.

**Chapter 4:** In this chapter 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.

**Chapter 5:** This chapter reviews different state-of-the-art damage detection methods and their recent advancement with a case study explaining the application of light detection and ranging (LiDAR) for pipeline damage detection. The pros and cons of diverse damage detection methods in pipeline networks are also discussed. Research gaps for pipeline damage detection systems are also provided for better understanding and future research. This chapter studies the feasibility of using TLS to perform structural deformation analysis. The associated steps to perform these analyses for a structural test specimen that suffered significant damage are outlined. The methodology given is intended to serve as a guideline for using TLS for structural experimentation in the future.

**Chapter 6:** In this chapter provides a detailed and systematic approach for extracting buildings, trees, and ground from a large point cloud geographical dataset, as well as performing deformation analysis of building columns using point cloud data. By following these steps, accurate and meaningful information can be obtained for further analysis and decision-making in various applications. For the extraction of buildings, trees, and ground points, the methodology utilizes a TLS scanner to generate a point cloud of the target area. Outliers are removed to improve data quality, and a grid is created to facilitate the identification and projection of building points.

Thresholds are set based on Z values to determine building and tree points, and these points are segmented from the remaining point cloud data.