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3D visualization of pavement distress using terrestrial LIDAR data

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Abstract

Terrestrial Laser Scanning (TLS) is a primal technique to obtain high quality 3D visualization models from dense point cloud data. TLS data is being used in several civil engineering fields such as Building Information Modelling (BIM), Pavement Condition Monitoring, etc. This paper focuses on the potential application of TLS point cloud data in the visualization of pavement distresses and in particular, the potholes on roads. Currently, the distresses like potholes are evaluated either through visual examination or images with the approximations. Nevertheless, the precise representation of the pothole is vital to appraise the severity of the distress and be efficacious in the maintenance of the pavement structure. The objective of this study is to use the point cloud data obtained from a terrestrial laser scanner for 3D visualization of potholes on a bituminous pavement and also to quantify it by measuring its accurate area. A road stretch in Vellore, India was taken and LIDAR survey was carried out with a terrestrial laser scanner. The collected point cloud data was then postprocessed to prepare a single LAS dataset with 6 mm accuracy. The area covered by the pothole was then clipped from the point cloud and then visualized three dimensionally by creating different perspective views in ArcGIS software. The results revealed that the LIDAR point clouds are one of the promising data sources for accurate 3D representation of pavement distresses.

1. Introduction

At present, India's National Highway (NH) system gauges around 1.5 lakh km. Of this total network, more than 77,000 km of highways has been constructed, expanded and strengthened between April 2014 and October 2022. This is greater than half of the nation's entire NH network (The Times of India, 2022). Also, through Pradhan Mantri Gram Sadak Yojana (PMGSY) scheme, the government of India has laid almost 430,000 km length of rural roads (Tawalare & Vasudeva Raju, 2016). At present the national highways authority of India (NHAI) is constructing 30 kms of new highways every day and as a result, the pavement evaluation, maintenance and management after completion of the work become very essential.

Pavement evaluation is generally carried out through field-testing and measurements or sometimes visual observation to describe the pavement's structural and functional integrity. The structural evaluation of the pavement deals with its ability to carry the present and future traffic, whereas the functional evaluation indicates its potential to supply a smooth, safe and a perfect ride quality surface (Joni et al., 2020). Functional evaluation holds the information on the characteristics of pavement, which are having significant impact on the safety and comfort of road users (Rusmanto et al., 2018).

Skid resistance, surface distress and road roughness are the primary qualities examined during the functional evaluation of pavement. Surface distress is basically the indication of upcoming failure or poor performance of the pavement through one or more of its signs such as cracking, rutting, potholes, bleeding, shoving, etc. They basically indicate the decline in pavement surface conditions. If unnoticed, they may even lead to safety issues in addition to vehicle delay, increase of fuel cost, etc. For example, in Bengaluru city in India, 6 deaths were reported due to potholes alone in a year (The Indian Express, 2022). Surface distress is generally measured through manual method (visual observation) and video recording methods (Kumar & Chandra, 2022). Even though science and technology is improving day by day, but still the majority of developing nations use the manual or visual observation technique for surface

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distress evaluation. The road maintenance organization's actual needs cannot be satisfied by these traditional detecting methods as its practically difficult to manually observe thousands of kilometers of roads across a country. Also, this visual observation and evaluation heavily dependent on the investigator's experience in identification as well as ranking of the distress. For example, a distress may be heavy but it may be wrongly recorded as medium or low. There may be combination of distresses at a location but instead it may be wrongly entered as single distress. In order to avoid all these issues with manual observation, nowadays sensor fitted vehicles are being employed. Distress data can be gathered using vehicles as road networks expanded over time and road data gathering using equipment also lowers rater's error, but it comes with a greater realization cost (Silyanov et al., 2020). To overcome all these drawbacks, rapid measurement techniques using terrestrial laser scanner, Unmanned Aerial Vehicles (UAV) mounted laser scanners have been widely employed nowadays (Valaskova et al., 2021). Point cloud data obtained through the Laser Scanning instrument has proved to be effectual in allowing engineers to build a 3D model of the all forms of distresses (De Blasiis et al., 2020; Ravi et al., 2020). Though there are many advantages in using laser scanning for distress evaluation, however only limited studies have been reported (Feng et al., 2022; Elseicy et al., 2022; Azam et al., 2023). Hence, in this study, LIDAR survey was carried out in order to explore its feasibility for distress identification and visualization. One of the popular distresses namely, the potholes were taken and the potential of the LIDAR in pothole identification and measurement was examined.

2. Method

2.1. Study Area

A pilot study was carried out to explore the feasibility of using laser point clouds to visualize the pothole in a three-dimensional way. For this, a 110 m long stretch of a flexible pavement near our Vellore Institute of Technology (VIT) campus was selected. A pothole of considerable dimension was found on this stretch as seen from Fig.1.

Figure 1. Pothole in the study stretch

2.2. Data Collection

The Leica BLK 360 terrestrial laser scanner was employed for laser scanning of the road section with potholes. The scanner works based on the remote sensing technique of Light Detection and Ranging (LIDAR), where the scanner emits 360,000 laser pulses per second and thus can produce a point cloud of millions of data points of X, Y, Z values finally. The scanner can scan up to a range of 60m and it is placed on the footpath of the roadway so that it can cover the entire pavement width along with the pothole. Two scans were taken on April 12, 2022 during high noon and Fig. 2 shows the HD photo of the study stretch taken by the BLK 360 scanner.

Figure 2. High-definition photo taken by the laser scanner showing the pavement with potholes

2.3. Methodology

The collected LIDAR Data were processed in Leica Cyclone Register 360 software. Point cloud created by laser scanning of the pavement and its surroundings is plotted in Fig.3. The pavement surface and its surroundings were exhibited as a cloud of points with spatial coordinates.

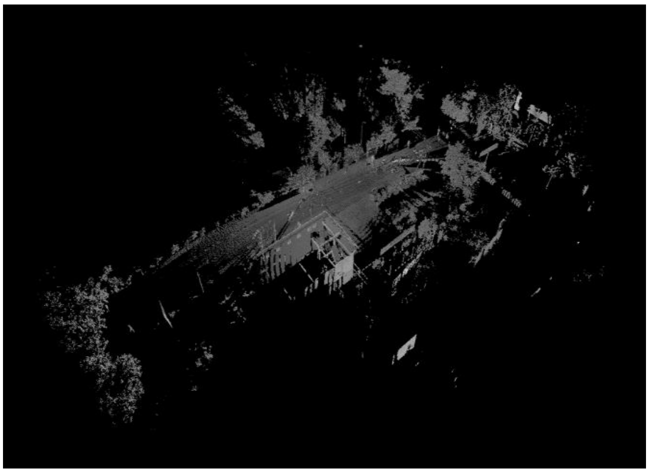

Figure 3. Point cloud from laser scanner

In the first step of post-processing of point cloud data, the scanned setups in BLK format are imported into the Leica Cyclone Register 360 software and the two scans were registered with an accuracy of 6 mm. This registered point cloud has 14,402,526 points. These points are returned from all the objects such as walls of the buildings, cars, moving objects, cables, tress etc. So, pavement surface should be extracted by removing the unwanted noises and the outliers from this cloud. By using the predefined tools in the processing software, the unwanted objects have been removed for further analysis. The point cloud after extracting the pavement surface is shown in Figure 4.

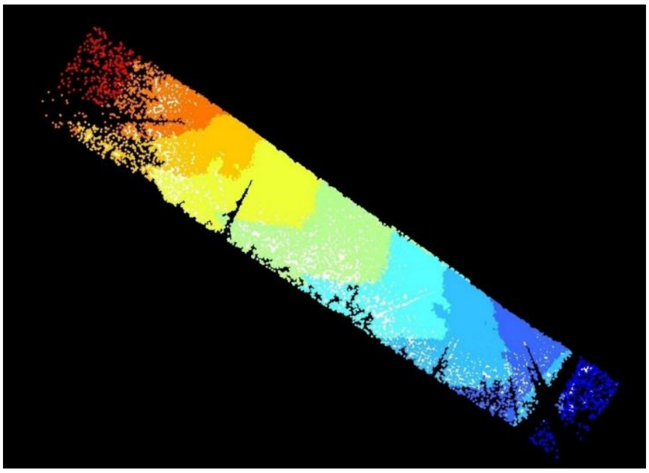

Figure 4. LAS dataset of the pavement surface

After removing the outliers, the remaining section alone has been exported to the .pts (a plain text file that stores point data, typically collected using a LIDAR scanner) format for further analysis. Next, the .pts file format has been converted into the .las format (which is a file format designed for the interchange and archiving of lidar point cloud data) using the Autodesk Recap software as shown in Fig.5. Finally, the .las format has been exported in to the ArcGIS platform for creating 3D scenes of the distress. By using 3D view option in the LAS Dataset toolbar, various 3D views of the pavement and the pothole were obtained.

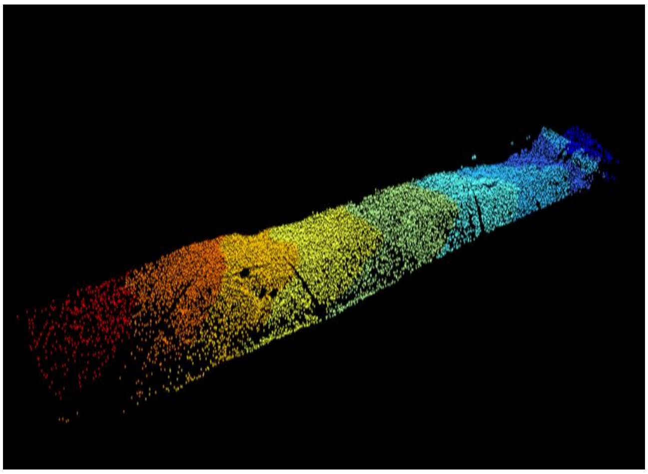

Figure 5. 3D view of the pavement surface

3. Results and Discussion

As we are interested in visualization of potholes, the same has been cut from the original LAS dataset and shown in Fig.6. The dense point cloud of the potholes captured from the TLS enable us in viewing the pothole from different perspectives. The top and side views of the potholes were showed in Figs. 7-9. One can nicely see the 3D model of the pothole and its extent from the Figs. 7-9. The depth of pothole is also pictured in Fig.10. As compared to the normal image, the views from the TLS derived point cloud gives more insight in determining the severity of the pothole. In addition to 3D visualization of potholes, one can also quantify the distress by measurement of its depth, area, etc. using the collected LIDAR data. Using Cyclone Register 360 software, the area of the pothole was measured as 4.644 sq.m. Thus, with the help of LIDAR data, one can visualize three dimensionally the distress condition and also can quantify it accurately.

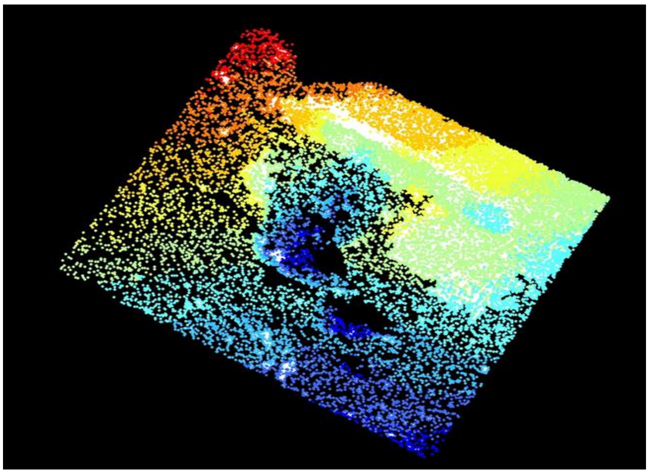

Figure 6. LAS dataset of the pothole

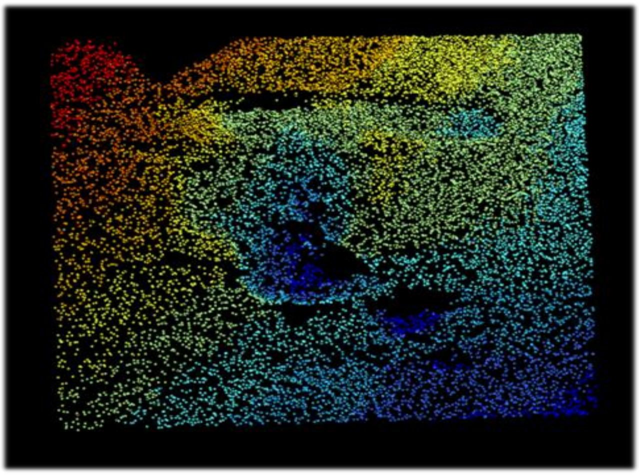

Figure 7. Top 3D view of the pothole

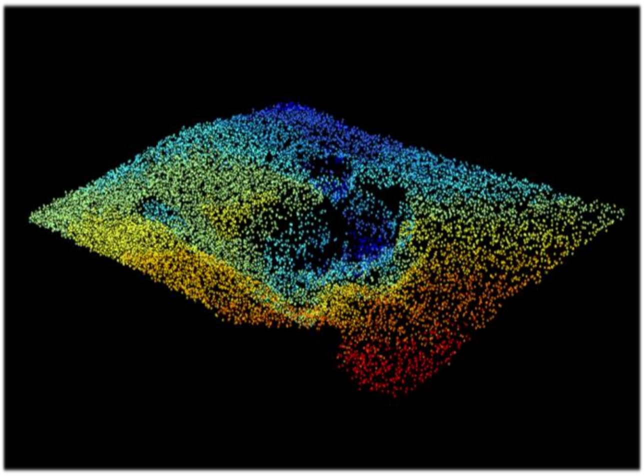

Figure 8. Side 3D view of the pothole

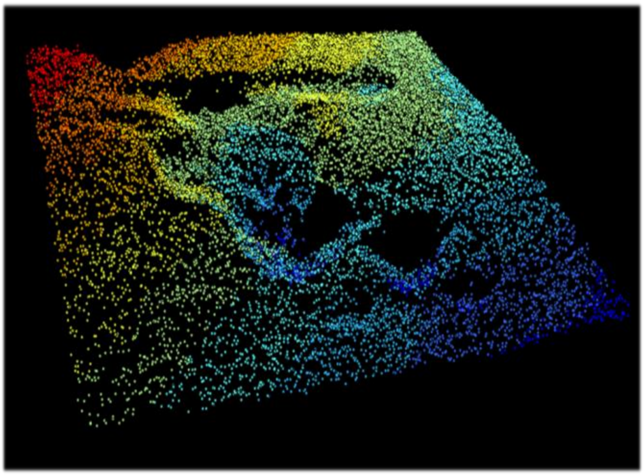

Figure 9. Side 3D view of the pothole

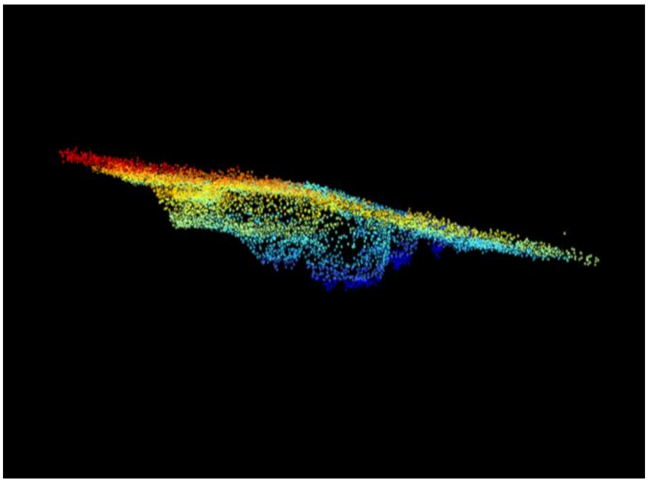

Figure 10. Side 3D view showing the depth of pothole

4. Conclusion

In this study, we showed the potential of TLS data for visualizing the pavement distresses mainly the potholes through various views and also the measurement of its areal extent. The results of our study demonstrate the effectiveness of using point cloud from LIDAR for the visualization of road surface distresses in a precise manner as the accuracy achieved was just '6 mm', less than a centimeter. A high density 3D model of the distress was created from the TLS point cloud data through laser scanning using terrestrial scanner and post processing using the TLS software. The results of this study are promising and thus suggests that LIDAR data can be used for functional evaluation of pavements rather than cumbersome manual methods.

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