ENHANCING POWERLINE MONITORING EFFICIENCY THROUGH AIRBORNE LIDAR AND SLAM

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***Abstract**: In today's interconnected world, the reliability of our electrical infrastructure is crucial. Powerlines are the lifelines of modern society, providing essential electricity to homes, businesses, and vital services. However, these critical assets face numerous challenges such as wear and tear of wires, environmental factors, and potential hazards. This is where powerline inspection becomes a required action. It plays a pivotal role in ensuring the safety and functionality of our electrical grids by identifying and addressing issues before they escalate into larger problems.*

This article delves into the practical implementation of LiDAR (Light Detection and Ranging) and SLAM (Simultaneous Localization and Mapping) technologies for powerline monitoring. It is focusing on how the fusion of data from these two sensors creates a complete dataset, essential for evaluating the state of electric infrastructure. Throughout, we'll explore how the synergy between LiDAR's precise 3D scanning capabilities and SLAM's real-time mapping enhances the efficiency and accuracy of powerline inspections. Additionally, the significance of this integrated approach in ensuring the reliability and safety of electrical networks will be discussed.

***Keywords**: 3D scanning; LiDAR; SLAM; powerline inspection*

1. Introduction

The growing dependence of modern societies on electricity is undeniable. Electrical companies face ongoing and considerable pressure to maintain a dependable supply and distribution of power. While trees, shrubs, and vegetation represent a considerable ecological and practical importance in our daily lives, their improper growth near powerlines can poses a significant risk to public safety and stands as a primary cause of power disruptions. To address these concerns, electric power distribution regulations mandate periodic inspections of powerlines and electric assets such as towers or transformers. These inspections involve detecting powerline defects, contamination of insulators, as well as detecting critical issues like sagging, wire contact with the ground, and interactions with various objects [5]. Traditionally, these inspections have been carried out manually by teams of workers using cranes, climbing equipment, or man-lifts to access the electric lines and assets. This process requires extensive manpower and work hours in hazardous environments. Lately, powerline inspections have been conducted using drones equipped with highly accurate LiDAR sensors and SLAM technology, to navigate and map the network surroundings in real time. This advanced technology offers several benefits as a tool for enhancing safety in powerline inspections [1],[2].

The registered progress of the unmanned aerial vehicles (UAVs), the availability of lightweight digital cameras, LiDAR and SLAM solutions have significantly slashed survey costs [3]. Calibration procedures for both airborne and terrestrial devices have emerged as a critical advancement in the initial phases of data processing. Furthermore, the ongoing development in calibration techniques has facilitated the diversification of applications for remote sensing technologies. While the early focus predominantly revolved around capturing terrain elevation data, recent advancements have expanded the scope to encompass a wide array of fields. Forestry and industrial reconstruction have emerged as standard areas of application, leveraging the capabilities of these technologies for tasks such as monitoring the vegetation, assessing industrial sites, and optimizing resource management practices [4].

In this continuum of progress, the integration of laser scanning for pole analysis represents a notable stride towards achieving enhanced accuracy and efficiency in infrastructure assessment and management. By utilizing laser scanning techniques, engineers and infrastructure professionals can obtain highly detailed and precise measurements of poles, facilitating better-informed decision-making processes regarding maintenance, replacement, and overall infrastructure planning.

This study aims to thoroughly investigate the evolving landscape of remote sensing technologies, with a particular emphasis on the development of calibration procedures for both, airborne and terrestrial devices. Through a detailed examination of methodologies and techniques, this research seeks to deepen our understanding on how these procedures enhance the precision and dependability of data gathered by remote sensing devices. Through this investigative process, the study seeks to offer valuable insights into the practical application of remote sensing and its significance in the context of powerline monitoring.

2. Data collection

This section provides an overview of the current advancements, aiming to demonstrate the practical application of TOPODRONE LiDAR 200+ system and SLAM 100 equipment in monitoring existing powerlines. Through an in-depth exploration of a powerline laser scanning project, will be illustrated how these cutting-edge technologies can be used to enhance the efficiency and effectiveness of powerline monitoring efforts. From capturing detailed scans of the infrastructure to analyzing the acquired data for identifying potential risks and areas of concern, we will delve into the various stages and processes involved in employing LiDAR and SLAM technologies for powerline management. By showcasing real-world examples, this article seeks to highlight the tangible benefits and advantages of integrating TOPODRONE LiDAR 100, SLAM 100 equipment and the afferent software, into powerline monitoring workflows.

TOPODRONE LiDAR 200+ Drawing upon the features of the Hesai XT32M2X, which boasts a 200-meter working range and a 120-meter flight altitude, this LiDAR device offers impressive capabilities. With a triple return mode yielding up to 1,920,000 points per second and XYZ accuracy ranging between 3 to 5 centimeters, it ensures precise data collection. Additionally, equipped with a 360-degree field of view (FOV), a built-in 200 Hz IMU boasting 0.07/0.01 accuracy, and a GNSS receiver, this lightweight device, stands as a formidable tool for aerial surveying and mapping tasks [6].

Moving forward to the mobile laser scanner equipment, the SLAM algorithms can operate without GNSS signal based on Hesai XT16. With a working range extending up to 100 meters and a remarkable scanning speed of up to 320,000 points per second, this device ensures efficient data acquisition. It boasts an impressive XYZ accuracy range of 3 to 5 centimeters, guaranteeing precise and reliable results. Additionally, equipped with three built-in cameras, the Hesai XT16 enables panoramic creation and point cloud coloring, enhancing the versatility and utility of its scanning capabilities [7].

Field work

In the realm of powerline analysis, the use of a DJI M210 v2 drone, outfitted with the LiDAR 200 + system and the Zenmuse X4S camera, has emerged as a transformative approach. However, the effective implementation of such technology necessitates careful flight planning and execution to ensure the fidelity and reliability of the collected data, subsequently facilitating insightful analysis.

At the core of this process lies the intricate synergy between the drone capabilities and LiDAR sensor. The TOPODRONE LiDAR 200+ boasts an advanced GNSS-based inertial navigation system, achieving an impressive accuracy. To harness this potential for powerline analysis, the planning phase initiates with a thorough study of the line's characteristics, including the terrain’s topography, vegetation cover, and potential obstacles. Simultaneously, the Zenmuse X4S camera plays an important role in capturing high-resolution aerial imagery. This visual component supplements the LiDAR data, providing context and detail that enriches the subsequent data processing analysis. Additionally, the camera's capabilities extend to contributing to the creation of orthomosaics and high-resolution digital elevation models (DEMs), consolidating the dataset generated during the survey.

Moreover, adding to all this process the SLAM technology, it plays a crucial role in enhancing the accuracy of ground structures, poles, terrain, and surrounding features by precisely mapping their spatial position. This comprehensive mapping not only improves the accuracy of asset identification and localization but also facilitates informed decision-making regarding infrastructure maintenance and optimization. By integrating SLAM data with other sensor inputs, such as GPS and IMU data, the overall accuracy and reliability of the mapping process are further enhanced, ensuring a higher understanding of the surroundings and infrastructure.

However, the transition from airborne data collection to insightful analysis poses its own set of challenges. The sheer volume of data acquired demands advanced processing techniques to refine and align the point clouds with imagery. This involves the use of specialized software to seamlessly fuse LiDAR and imagery datasets, ensuring that the resultant models accurately reflect the surveyed powerline infrastructure. Advanced algorithms create noise reduction, data filtering, and feature extraction, ultimately producing a refined dataset conducive to detailed analysis and actionable insights.

Data processing

Before detailed processing can commence, several initial preprocessing steps are conducted, preparing it for thorough analysis. Post-processing and image geotagging are also essential components in extracting precise and meaningful insights from the measurements, especially when leveraging both cameras and LiDAR sensor. After completing the flight mission, transferring the UBX file from the GNSS receiver's SD card to a designated folder on the computer and converting the base station file into RINEX format, are necessary steps in the process. These intricate procedures are fundamental to converting raw data into actionable information for a wider range of applications.

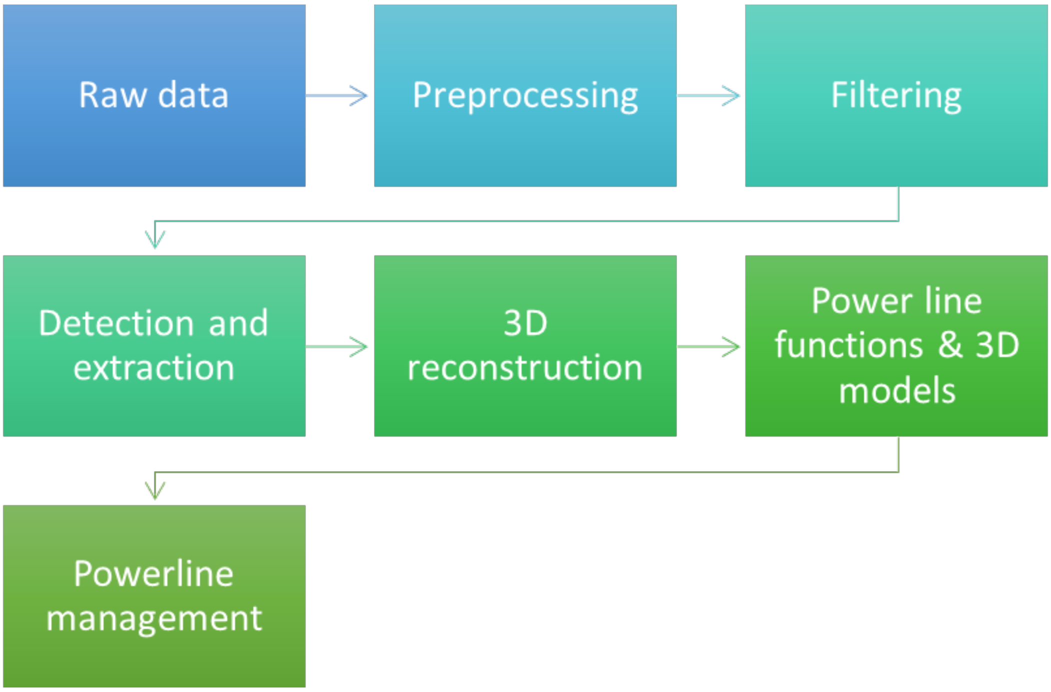

Figure 1. Workflow of 3D powerline management – [8]

In the subsequent phase, the high-precision trajectory was calculated, using the combined data from GNSS stored throughout the mission. Following this critical step, the LiDAR point cloud generation process was initiated, capturing the details of the surveyed area. Notably, the quality of the point cloud acquired by the LiDAR system is worth emphasizing. Following the generation of the point cloud, the focus shifted towards the automatic classification and detection of key features within the surveyed landscape. This included identifying and delineating elements of interest such as power line towers, wires, vegetation cover, and other significant objects [5], as shown on the figures 2-4, which present the point cloud obtained from merging the LiDAR and SLAM capabilities. To obtain this 3D representation of poles with high accuracy was used LiDAR360 software, in which users can first generate the representation of poles in a 3D space. Then, they can apply various filters to achieve a thematic representation, allowing for the highlighting of specific characteristics or attributes of the poles based on certain criteria.

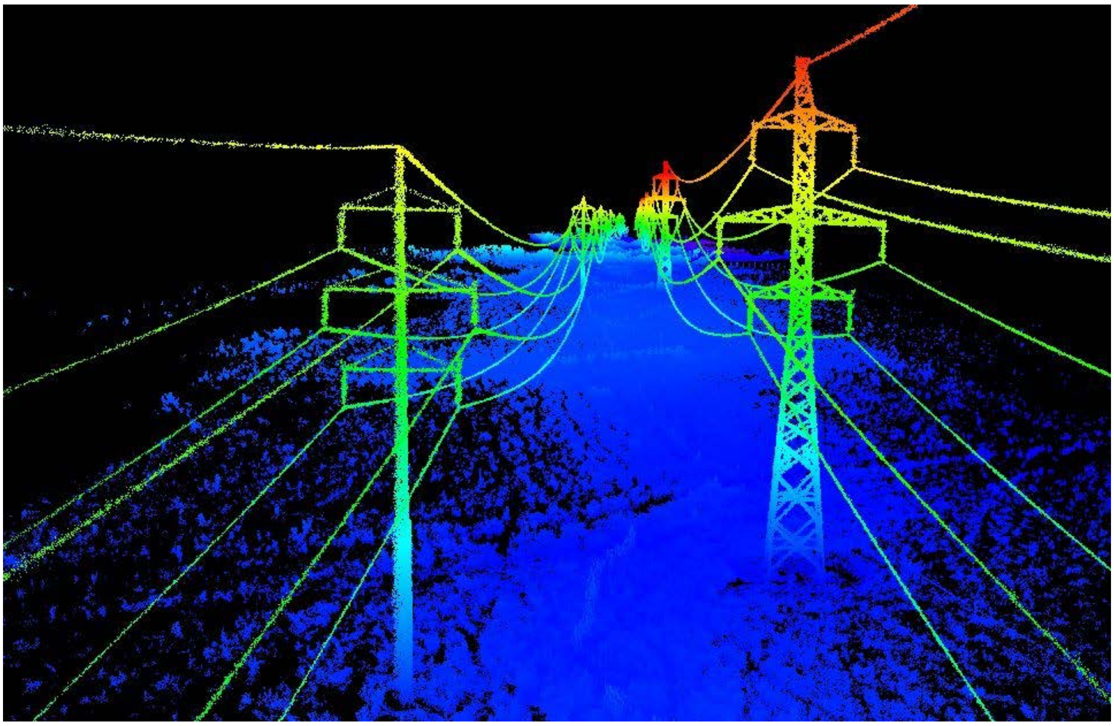

Figure 2. SLAM results

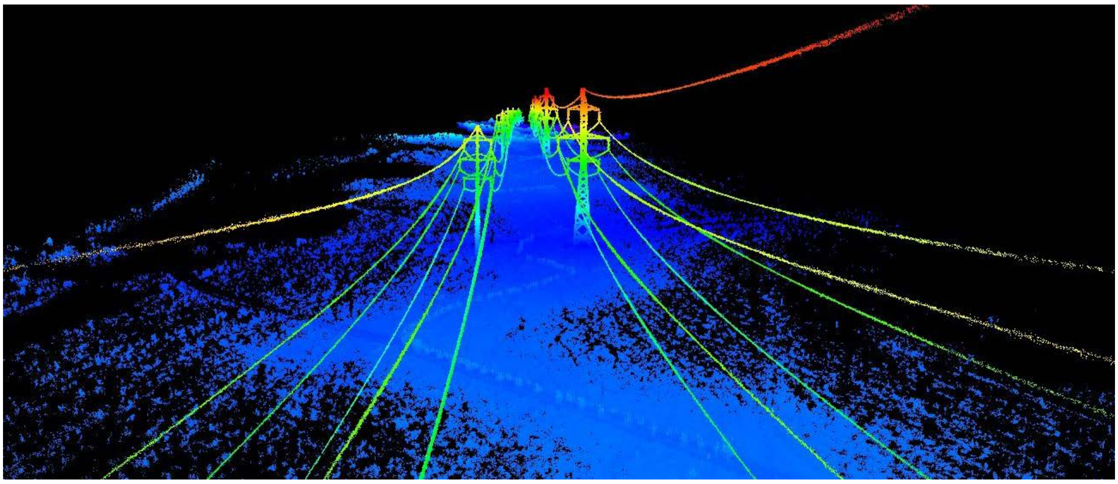

Figure 3. 3D view of the powerlines

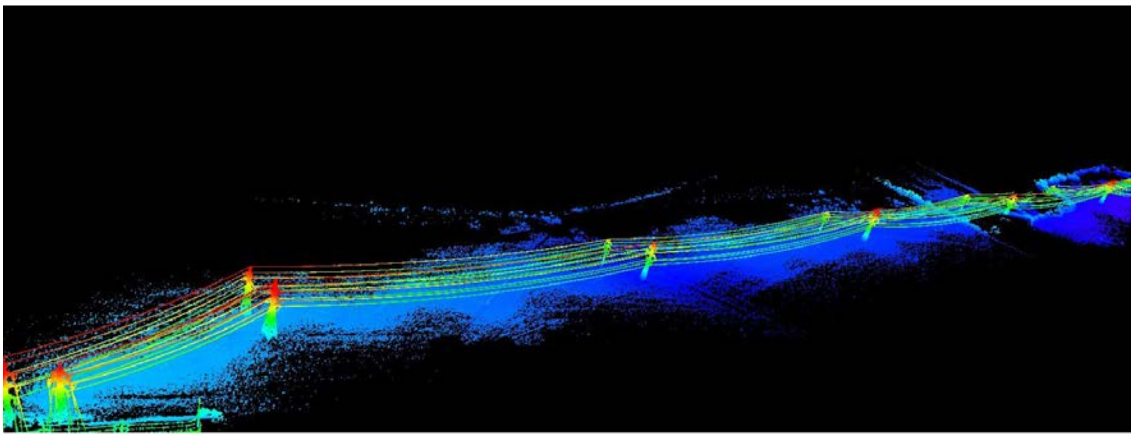

Figure 4. The path of the powerlines

Additionally, LiDAR360 provides tools for measuring the height, diameter, and other relevant dimensions of poles, as well as tools for assessing their structural integrity and health. These tools enable users to conduct comprehensive inspections and analyses of poles for various applications. By integrating these tools, LiDAR360 empowers users to conduct thorough inspections of poles, assess their condition, and make informed decisions regarding maintenance, replacement, or other necessary actions. This comprehensive suite of tools enhances the efficiency and effectiveness of pole inspection workflows, ultimately contributing to safer and more reliable infrastructure management.

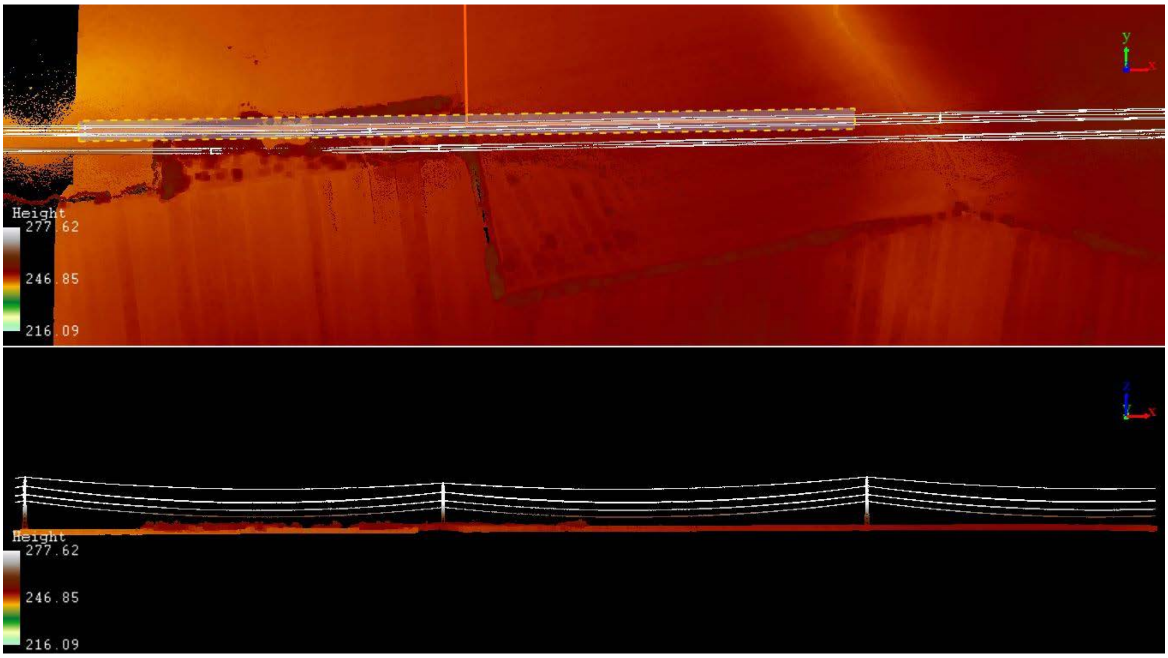

Figure 5. Longitudinal section of the powerlines

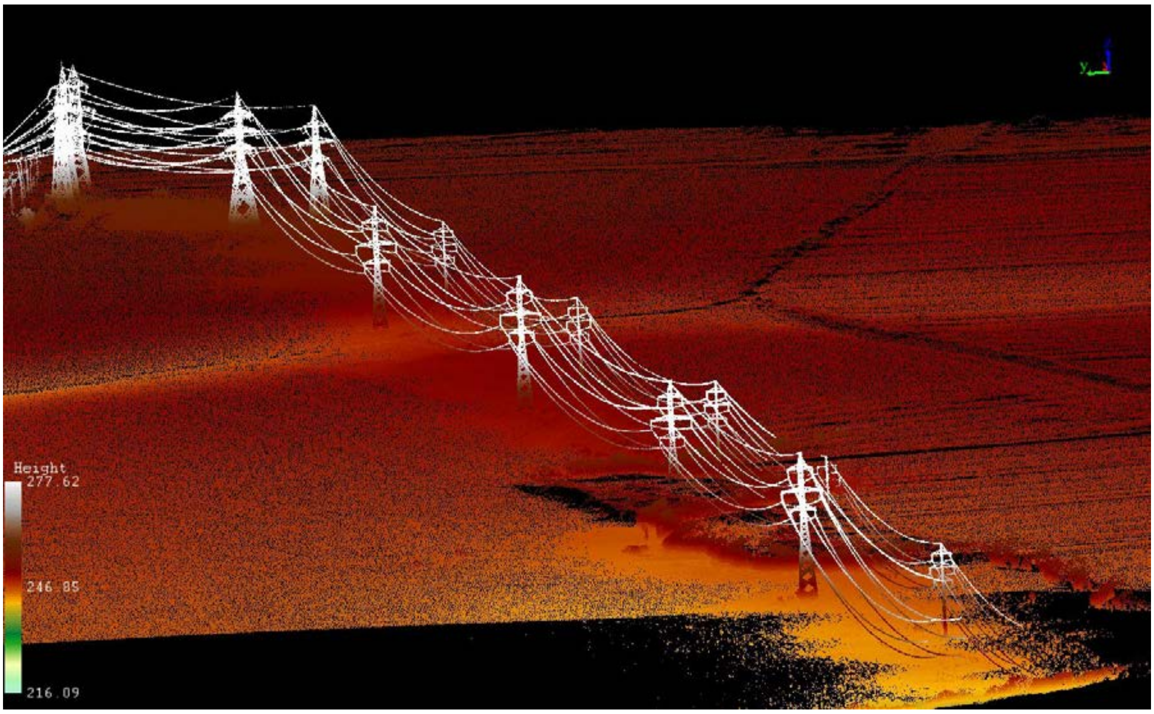

Figure 6. Overview of the powerlines

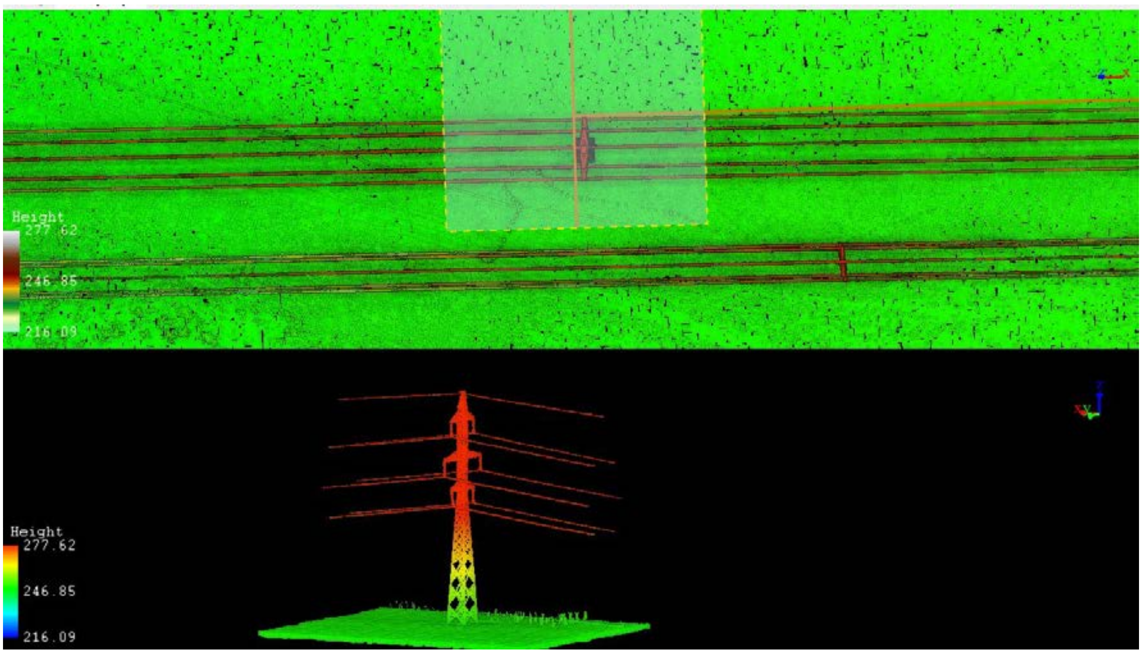

Figure 7. Cross section of the powerline pole

3. Conclusion

The integration of LiDAR and SLAM technologies for powerline monitoring represents a significant advancement in ensuring the reliability and safety of electrical infrastructure. By combining precise 3D scanning capabilities with real-time mapping, this integrated approach offers numerous benefits in powerline inspection. Through the practical implementation of TOPODRONE LiDAR 200+ and SLAM 100 equipment, this article has demonstrated how these cutting-edge technologies enhance the efficiency and effectiveness of powerline monitoring efforts. From capturing detailed scans of the infrastructure to analyzing the acquired data for identifying potential risks and areas of concern, the synergy between LiDAR and SLAM facilitates comprehensive powerline management.

Furthermore, the article highlights the significance of data fusion and processing in generating actionable insights from the collected data. By leveraging advanced algorithms and software tools, such as LiDAR360, users can extract precise measurements, assess structural integrity, and make informed decisions regarding maintenance and optimization of powerline assets.

Overall, the integration of LiDAR and SLAM technologies, coupled with advanced data processing techniques, empowers electric utility companies to conduct thorough inspections, mitigate risks, and ensure the continued reliability of electrical grids. As society's reliance on electricity continues to grow, the importance of innovative approaches to powerline monitoring cannot be overstated, and LiDAR and SLAM technology are at the forefront of driving advancements in this critical field.

4. References

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