GEODETIC UTILIZATION OF TERRESTRIAL LASER SCANNERS

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ABSTRACT:

The ancient aspiration of geodesists and astronomers, rooted in ancient Greece, aimed to comprehend the world's magnificence. Today, with virtual atlases facilitating planetary exploration, the world is accessible at our fingertips. Laser scanning, an efficient method for 3D modelling, has revolutionized data collection, processing, and visualization. This encompasses a master's thesis on scanning the Clinical Center of Serbia, regulated for laser device design, operation, and maintenance across diverse sectors.

Terrestrial laser scanning, evolving since the 1990s, has seen a surge in 3D modelling applications. Notably, in traffic accident reconstruction, it swiftly clears debris while providing a comprehensive three-dimensional representation. Despite challenges like scanning vehicle surfaces with metallic paints, the precision of data makes it suitable for reconstruction purposes. LIDAR technology, developed over four decades, is now integral in forestry for assessing terrain beneath forest structures, generating digital terrain models, tree heights, and forest structure information.

The principle of laser scanner operation lies in measuring polar coordinates and distances to specific points in space. Scanners come in three types—camera, panoramic, and hybrid scanners—each with unique characteristics. Terrestrial scanners, classified by distance measurement methods (pulse, phase, triangulation), enable rapid data capture with higher density than total stations. The Leica ScanStation P30, employed in scanning the Clinical Center of Serbia, offers high-quality 3D data with exceptional speed and accuracy. Utilizing backward intersection methods and Leica TS11 total station for marking, the scanner captured the facility's exterior in 2022. Data processing in CYCLONE resulted in highly detailed 3D models, and the .imp format allows portable and adaptable changes without losing essential information.

Laser scanning has transcended ancient dreams, providing a transformative tool for understanding and representing our world's intricate details. The application spans diverse fields, from geodesy and traffic accident reconstruction to forestry and facility modelling, with advanced technologies like LIDAR and instruments like the Leica ScanStation P30 pushing the boundaries of data collection and processing in three-dimensional space.

KEYWORDS:

terrestrial laser scanning, 3D modelling, LIDAR, georeferencing

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1 INTRODUCTION

The ancient dream of the first geodesists and astronomers, dating back to the era of ancient Greece, was to comprehend the world as it truly is in its full magnificence. Today, the world is at our fingertips, considering the vast number of virtual atlases that enable virtual tours of planets and celestial bodies.

2 LASER SCANNING

Laser scanning represents an efficient method for quickly gathering data for 3D modelling, facilitating the processing, modelling, and visualization of scanned objects in various fields [2]. This includes the task of a master's thesis on scanning the Clinical Center of Serbia. This regulation prescribes the conditions and requirements for the design, operation, and maintenance of laser devices and systems. Additionally, it defines the procedure and method of labelling and marking lasers, as well as technical measures for protection [6]. The regulation applies to laser devices used in various sectors, including industry, medicine, education, entertainment, and telecommunications. These provisions encompass laser devices with or without a specific power source, as well as complex optoelectronic systems with multiple lasers. Furthermore, the regulation stipulates the procedure for maintaining specific properties and the quality of lasers during their use. Laser scanning involves capturing the spatial data of an object using lasers, resulting in a three-dimensional point cloud with X, Y and Z coordinates. The spatial distance between adjacent points within the point cloud depends on the distance from the scanned object and the technical specifications of the instrument, allowing for high-density point clouds. Static laser scanning occurs when the laser scanner is fixed during the recording process, while dynamic laser scanning involves a mobile platform, such as airborne scanning or scanning from a moving vehicle. Both methods require positioning systems like GPS for spatial reference. The application of terrestrial laser scanners yields precise data, enabling the construction of 3D models and serving as a rich source of information about the observed object. The wide-ranging uses of laser scanners include measurements comparable to traditional geodetic instruments, recording and marking objects, monitoring deformations, and capturing industrial facilities.

Figure 1: Laser scanning

3 TERRESTRIAL LASER SCANNING

Terrestrial laser scanning has been used in geodesy since the 1990s, but it has undergone significant development in 3D object modelling since the early 21st century [5]. The application of laser scanning in traffic accident reconstruction enables the swift removal of vehicle debris from the road while simultaneously collecting all essential information, making it the only method that provides a three-dimensional representation of the entire accident scene. Although laser scanning has its drawbacks, such as difficulties in scanning vehicle surfaces due to metallic paints and glass parts, the precision of the data obtained by this method is satisfactory for the purposes of traffic accident reconstruction. LIDAR technology has been developed over the last 40 years and was initially used for mapping particles in the atmosphere, particularly in atmospheric and meteorological research. The development of LIDAR systems was slow due to high costs, but private companies have taken over the technology in the last decade, entering mass production and enriching the market with various laser systems. LIDAR is employed in forestry to measure the three-dimensional structure of forest areas, providing information about the terrain beneath the forest structures. A wide range of information, including digital terrain models, tree heights, digital surface models, and forest structure, can be directly obtained from LIDAR, while processed data reveal various characteristics of forest cover [4].

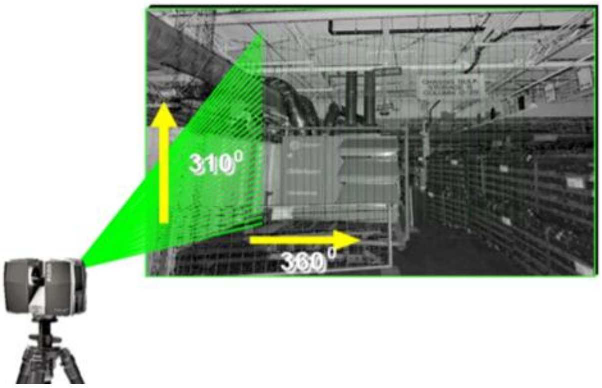

Figure 2: Terrestrial laser scanner

4 THE PRINCIPLE OF OPERATION LASER SCANNING

For forest inventory, LIDAR is predominantly used to obtain basic structural attributes of trees, including height, canopy cover, and vertical profiles [4]. These data can be utilized for various measures, including log and timber volume, as well as biomass for alternative energy analysis and carbon sequestration. The principle of operation of laser scanners is based on measuring polar coordinates, i.e., horizontal and vertical angles, and the distance to a specific point in space [2,3]. Laser scanners are used to capture the desired object by measuring a large number of points and their 3D coordinates while measuring the distance to each point in the point cloud. An important aspect of laser scanner construction is directing the laser beam, which is achieved by rotating the laser beam in space through the rotation of mirrors. This approach allows scanning of the desired object and obtaining spatial coordinates of points [5]. There are three types of terrestrial scanners based on the scanning method, including camera scanners, panoramic scanners, and hybrid scanners, each with its own characteristics and limitations. Terrestrial laser scanners are classified based on distance measurement methods using pulse, phase, and triangulation methods, which can also be combined. The pulse method allows for measuring long distances but with reduced accuracy, while the phase method provides high accuracy but with a limited range. The triangulation method achieves high accuracy but has a limited range. Pulse distance measurement, widely applied, combines measured distances with spatial angles to obtain three-dimensional coordinates. Scanners are also categorized based on data collection methods into absolute (georeferenced) and relative (local) point clouds, with newer scanner generations incorporating compensators for direct georeferencing of on-site data. Terrestrial laser scanners enable rapid capture of a large quantity of points with significantly higher data density compared to total stations. The key differences between terrestrial laser scanners and total stations lie in the recording speed of individual points and accuracy. Terrestrial laser scanners capture thousands to millions of points per second, while total stations measure the length multiple times for each point. The high scanning speed of terrestrial laser scanners enhances the productivity of geodetic teams in the field, reducing the time needed for point measurements and allowing for automatic recording of point clouds with equal value, simplifying the sketching process [5].

5 LASER SCANNER LEICA SCANSTATION P30

The Leica ScanStation P30 laser scanner was used to scan the construction of the Clinical Center of Serbia, providing high-quality 3D data with high scanning speed and accuracy in ranges up to 130 m. Field measurements were conducted from May 2019 to April 2020, involving two surveying engineers and two surveying technicians. Scanner orientation was performed using backward intersection methods and selected points as references. The Leica ScanStation P30 allows scanning of the entire object with exceptional point density, and the obtained point cloud was used for facade design. After design, facade elements were marked using the Leica TS11 total station based on coordinates obtained from the project. During 2022, the Clinical Center of Serbia was scanned externally using the Leica Scan Station P30, utilizing nine stations to capture various parts of the facility. All collected data were processed in CYCLONE, where scans were meticulously processed and associated to obtain the final and unified point clouds of the Clinical Center of Serbia's exterior, representing highly detailed 3D models. Configuring the database in CYCLONE Navigator is the initial step, allowing manipulation of the point cloud. The point cloud in .imp format is portable and amenable to changes and corrections without losing essential information.

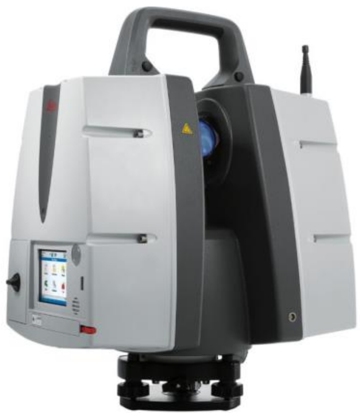

Figure 3: Leica ScanStation P3

6 CONCLUSION

Terrestrial laser scanners have revolutionized geodetic data collection, providing rapid and high-density point cloud acquisition for diverse applications. The utilization of advanced laser scanning technologies, exemplified by the Leica ScanStation P30, significantly enhances the efficiency of field measurements, offering precise 3D data for complex structures like the Clinical Center of Serbia. The seamless integration of laser scanning into geodetic workflows showcases its pivotal role in achieving detailed and accurate spatial information for applications ranging from traffic accident reconstruction to forestry management. Overall, the continual development of laser scanning techniques underscores its indispensable contribution to modern geodetic practices.

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