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Original Contribution

ASSESSMENT AND MONITORING OF ROAD MARKING REFLECTIVITY USING MOBILE LASER SCANNING TO IMPROVE ROAD SAFETY

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ABSTRACT

The reflectivity of road markings is a crucial factor for safe road conditions, improving visibility in adverse weather. Over time, markings lose their effectiveness due to wear, increasing the risk of accidents. This analysis discusses monitoring methods, with special attention to the application of mobile laser scanning (MLS). The technology provides accurate and reliable data on the condition of markings, enabling timely maintenance. Using mobile laser scanning not only speeds up the inspection process, but also supports informed decision-making. Integrating this technology into road infrastructure management (specifically road markings) is an important step towards improving the safety and efficiency of the transport system.

Keywords: road safety, visibility, deterioration of markings, infrastructure management

INTRODUCTION

Information about the reflectivity of road markings is essential for assessing their condition and effectiveness (1). The ability of markings to reflect light is a key factor improving visibility and road safety, especially at night or in poor weather conditions. Markings with higher reflectivity provide better visibility for drivers, which is crucial for preventing accidents (2). This property of road markings is directly related to their physical condition. Over time, markings wear out, leading to a progressive decrease in reflectivity and, consequently, poorer visibility. Monitoring reflectivity can indicate the need for timely preventive actions, as markings with lower reflectivity often increase the risk of accidents (3,4).

MATERIALS AND METHODS

The significance of road markings plays an extremely important role in traffic safety. Numerous examples highlight their importance in road safety:

1. In foggy conditions, road markings serve as a primary guide for drivers, helping them maintain the correct direction and avoid accidents. Clearly visible and well-maintained markings significantly reduce the risk of accidents in limited visibility, as drivers rely on visual cues (5). Determining effective road boundaries is essential to prevent fatal deviations.
2. With the development of the automotive industry and the introduction of technologies in new generations of vehicles, there is increasing reliance on driver assistance systems, including functions for automatic "return" of the vehicle to the correct lane (Lane Departure Alert - LDA). These systems use information from road markings to determine lane boundaries and prevent unwanted deviations (6). For example, Lane Departure Warning (LDW) systems rely on accurate recognition of markings to alert the driver when the vehicle begins to leave the designated lane. In areas with frequent snowfall, the use of yellow markings can be considered. These are typically used for temporary restrictions, such as repairs or road changes, but also offer better visibility in snowy conditions, as they contrast against the white snow, which is especially important for drivers and driving assistance systems (7).
3. When changing lanes, road markings also play a crucial role in road traffic safety. Clearly marked lines help drivers make

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informed decisions when changing lanes. Properly designed and executed markings can reduce incidents related to improper lane changes by providing clear visual cues for safe manoeuvring.

4. Road markings can be designed to produce audible signals (when crossed by a vehicle), increasing driver attention. For example, markings that create noise when tyres pass over them can serve as an additional warning mechanism, especially when the driver is distracted or tired.
5. Clearly marked pedestrian crossings also play a significant role in road traffic safety for both passengers and drivers. They serve not only as visual cues for drivers but also as protection for pedestrians, providing a safe way to cross streets. Well-marked and maintained crossings increase the chances of pedestrians being noticed in time by drivers, which is essential for preventing accidents (8).

Ground-based laser scanning (especially the mobile version) is an innovative method for collecting data on the condition of road markings (9). This method allows for rapid and detailed extraction of information about road markings, which in turn helps identify problems such as wear or damage. Using such hybrid laser systems **(Figure 1)** for road marking analysis ensures high accuracy, timeliness, and reliability of results, which is essential for planning and proper maintenance of road infrastructure.

Figure 1. Integrated Laser System "RIEGL VMZ"

RESULTS

Mobile LiDAR systems can generate and accumulate large volumes of data in a short time. They are designed to operate under various lighting conditions, making them a powerful source of accurate and reliable data, even in adverse weather (3, 10).

A key factor of the effectiveness of LiDAR systems in assessing and monitoring road marking conditions is their ability to accumulate 3D point cloud that contain information about the reflectivity of the object that is being measured. These systems can provide precise measurements of the geometry and reflectivity of different markings **(Figure 2),** allowing road authorities to identify sections that require new markings (12).

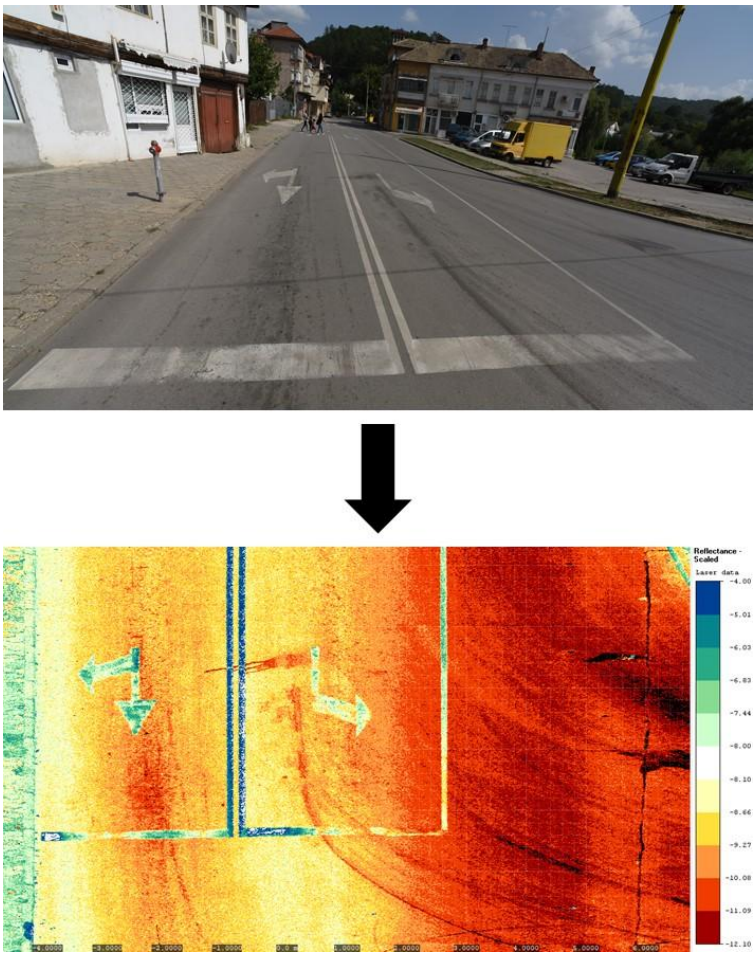

Figure 2. Reflectivity of different markings

Figure 3 shows two different methods for visualising the point cloud using variations in electromagnetic spectrum intensity. On the left is a 3D point cloud where the intensity of reflected light is set only for highly reflective surfaces (such as the road surface), and on the right is the result of processing with a spectral filter, highlighting differences in reflectivity between different surface types (asphalt in red and road marking in green).

By applying special classification algorithms and spectrum intensity to data obtained from mobile laser scanning, road authorities could semi-automate the inspection process, identifying and classifying the condition of road markings using the above-mentioned objective and measurable indicators. This allows maintenance planning not only based on visual observations but also through quantitative analysis, leading to more efficient resource allocation and improved road safety.

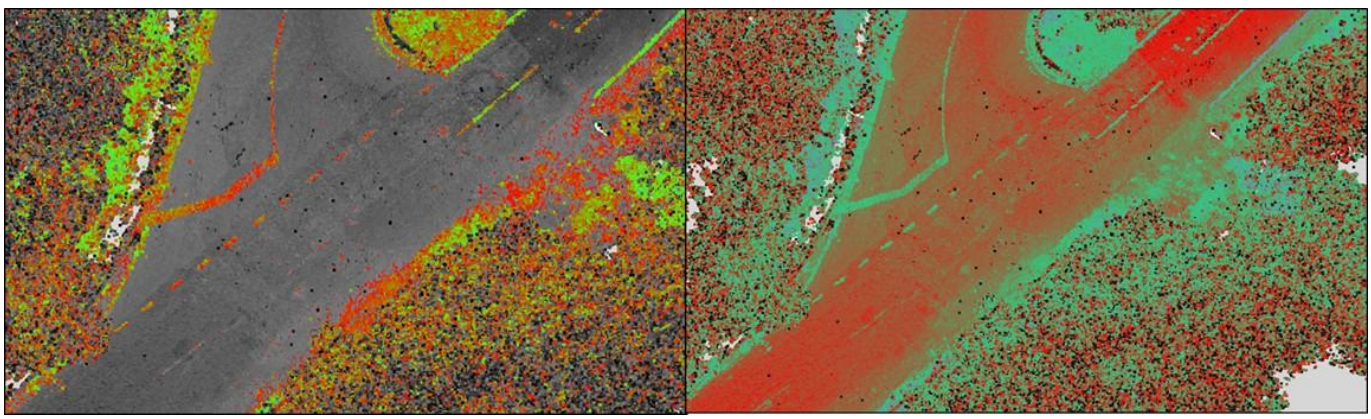

Figure 3. Visualising the point cloud using variations in electromagnetic spectrum intensity

A major advantage of this technology is its complete independence from external factors and traffic conditions. The scanning process is not affected by the time of day, nor by passing through tunnels, dense vegetation, or sections with complex terrain. Another significant advantage is that during scanning, there is no need to close road sections or restrict traffic. Measurements can be carried out under real traffic conditions without disrupting normal transport flow (13). If necessary, to achieve full coverage and eliminate possible "blind spots," the route can be scanned multiple times, ensuring high accuracy and detail of the data (10, 13). Checking and studying road markings using modern technologies, such as mobile laser scanning is an important aspect of maintaining road safety. Investing in new technologies for monitoring road markings can lead to significant improvements in traffic safety and reduce road accidents. By using these technologies, road authorities can accurately assess the condition of markings and take necessary maintenance measures, which is essential for traffic safety.

DISCUSSION

The benefits of mobile laser scanning go far beyond just assessing markings. MTLS is widely used in all stages of the road infrastructure lifecycle (4, 14) – from design, through construction and repair, to maintenance and control. The technology proves its effectiveness not only under standard conditions but also on hard-to-reach and risky terrains, where traditional surveying methods are difficult or even dangerous. Additionally, the ability of direct integration of MLS collected data into GIS and CAD systems facilitates the creation of digital twins and accurate infrastructure models.

CONCLUSION

Inarguably, road markings are essential for traffic safety. Maintaining high standards of visibility and quality of markings is key to road safety. Therefore, their inspection and maintenance are crucial for preventing accidents and ensuring safe driving.

Mobile laser scanning is a powerful tool with a wide range of applications in the road sector. Beyond facilitating the monitoring of road markings, MTSL also provides a comprehensive, accurate, and efficient basis for decision-making at every stage of the road infrastructure management process. Integrating this technology into practice is a strategic step towards improving the safety, efficiency, and sustainability of the transport system.

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