LIDAR INFRASTRUCTURE TRAFFIC MONITORING

A QUIET DIGITAL MAP OF THE WORLD

Just as modern vehicles are becoming smarter and more autonomous, we explore how to make infrastructure more intelligent. This white paper provides insights on automated safety based on LiDAR infrastructure monitoring to ensure the safety for all road users.

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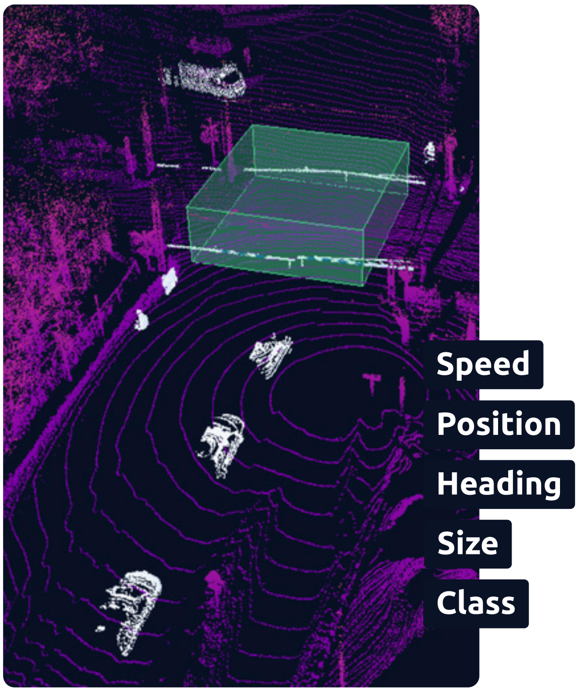
Executive Summary

The LiDAR (Light Detection and Ranging) technology is essential for autonomous vehicles and robots, offering a high-resolution digital representation of the physical environment using laser pulses. This spatial awareness is crucial for safe navigation in real-world environments. To achieve traffic-safe autonomous operation, smart infrastructure is a vital complement to sensors mounted on the vehicle itself. Fixed LiDAR sensors in the infrastructure can provide comprehensive environmental data to both human drivers and autonomous vehicles, enhancing overall safety.

LiDAR in the infrastructure VS. LiDAR on the vehicles

- Smart infrastructure is feasible, cost-effective, and powerful, particularly when all activities and traffic occur in confined areas, such as industrial zones.
- Instead of each vehicle being responsible for its own safety, fixed LiDAR sensors in the infrastructure can provide both human drivers and autonomous vehicles with comprehensive environmental information, which individual vehicles may lack [4].



The goal to reduce human errors

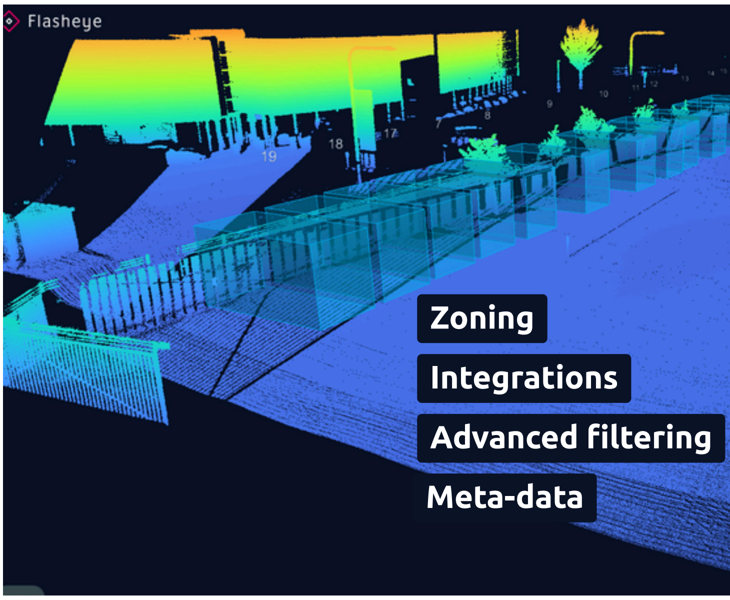
The human factor is responsible for approximately 95% of accidents. Urban areas account for 38% of failures, while only 7% occur on highways. Interestingly, only about 16% of errors are related to cloudy weather, and just 1% occur during rainy or snowy conditions. Most disengagements (82%) happen in good weather, demonstrating that most errors are not linked to bad weather conditions [28]. To achieve Vision Zero, the human factor must be addressed.

Increased interest in ITS

Intelligent Traffic Systems market growth is projected to reach USD 27.56 Billion by 2030, with an annual growth rate of 12.3% [26], driven by safety and automation. Even modern vehicles equipped with driver assistance systems, designed to reduce accidents and optimize driving, would benefit from external environmental data. LiDAR is widely used in automotive and robotics for collision avoidance and perception, e.g. detecting objects hundreds of meters away, enabling vehicles to stop at high speeds.

Outstanding and reliable 3D data

By utilizing information from the infrastructure, we can accurately track surrounding vehicles' positions in real-time, allowing prediction of potential risks. This information plays a crucial role in the development of autonomous systems that can respond more quickly and precisely to changes in traffic dynamics [6], [22].



Addressing the challenges in ITS

The total understanding of the surroundings is missing

Signalized intersections, commonly used to manage traffic, often become hotspots for incidents due to ground sensors for vehicles and activation buttons for pedestrians that control light signals [3]. These intersections lack the intelligence to fully understand all situations, leading to accidents [4], [18], [25]. LiDAR technology and perception software can address this with reliable real-time monitoring of everything that moves in the scene to prevent incidents and enhance traffic flow [3], [4], [18], [22], [24]. With real-time awareness, drivers can be alerted or traffic lights controlled more intelligently than today's systems or provide the existing system with new information [3], [18], [24]. Additionally, LiDAR in the infrastructure provides a bird's-eye view of the scene, which vehicle sensors cannot.

Real-life scenarios are complex, and conditions are various

A smart system must handle challenges like extreme weather (rain, snow, fog), urban issues (shadows, reflections, potholes, poor lighting), and unique situations (exhaust emissions, smooth surface reflections, and open vehicle doors). Cameras struggle with poor lighting, especially at night, making them unsuitable for real-time data [14], [25]. A comparison of video and LiDAR shows that while LiDAR performs similarly during the day, it outperforms video in low-light conditions, such as late evening [25], and strong sunlight, which is a known problem for cameras.

Overview of existing technologies

LiDAR technology is not expensive and out of reach anymore

While technologies like cameras and radar lack the precision of LiDAR [8], [17], [25], LiDAR has traditionally been too expensive for widespread use in driver assistance systems. However, as LiDAR prices decrease with growing popularity, it is now becoming feasible to install in traffic systems [17], [24], [18]. This enables the shift to smart cities, where vehicles can connect to infrastructure for safer traffic and LiDAR monitoring can provide traditional systems, such as traffic lights, with situational awareness [3], [4], [17].

Video and radar provide limited information and lack reliability

Cameras, now popular for their cost-effectiveness, provide detailed analysis and advanced object classification in favorable conditions [25], [28]. However, they struggle with visibility issues and 3D scene representation, making them less effective in real-time safety-critical systems. Using two cameras to create a 3D point cloud can address this, but real-time 3D object detection remains challenging. Radar, effective for medium to long-range mapping and poor weather conditions, detects objects up to 150 meters, far surpassing the 10-meter range of human drivers in similar conditions. However, radar lacks the fine resolution needed for precise object identification, making it less suitable for detailed scene analysis [28]. While video and radar are complementary, LiDAR provides both spatial perception and precision for understanding surroundings and classifying objects.

Both cameras and radar have limited fields of view, leading to blind spots, a problem LiDAR in the infrastructure avoids with its wide-area, high-quality data [7], [14], [25]. Offering 360-degree, high-resolution mapping across short and long ranges, LiDAR excels in low-visibility and poor lighting conditions, making it the standard sensor for many advanced systems [7]. Active sensing, such as RADAR, LiDAR, and ultrasound, emits signals and detects reflections, allowing control over frequency and direction in various conditions. In contrast, passive sensing, like cameras, captures environmental signals without emitting energy [28].

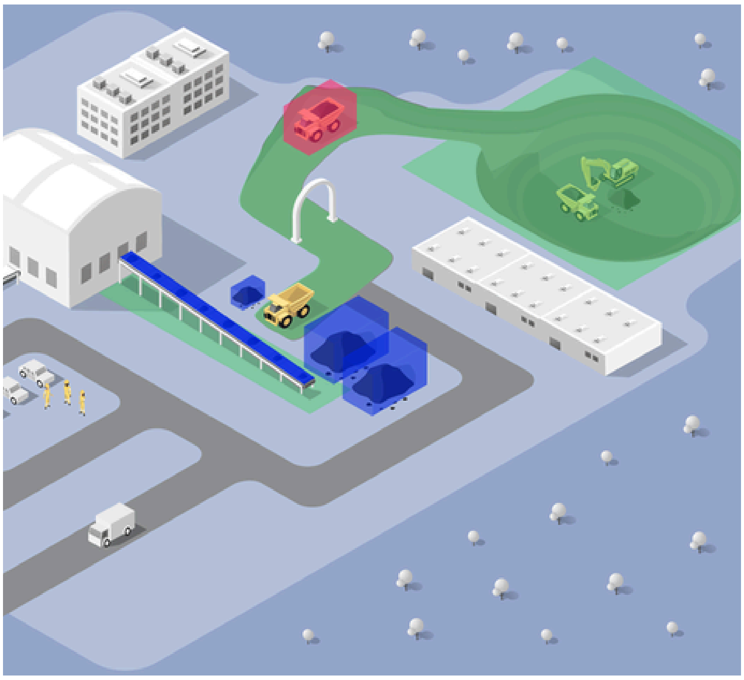
Capabilities needed for a smart traffic monitoring system

Purpose	Capabilities
High reliability under various conditions	• Not sensitive to light and weather conditions • Real-time and minimal latency
Cost effective	• Easy implementation • Optimized field of view • Coverage of large areas
High accruacy and precision	• Spatial perception of the environment • High visibility • Detailed and accurate information about each object

Intelligent traffic lights

Traffic light control is a basic ITS application that optimizes traffic flow and improves safety by reducing jams, lowering driver stress, and protecting vulnerable road users (VRUs).

Key hazards involve timing transitions and preventing conflicting green lights.
ITS systems for traffic light control can be implemented straightforwardly by ensuring safety requirements at lower levels and adding higher-level ITS functions without compromising safety. A LiDAR-based system offers the advantage of anonymized data for GDPR compliance, allowing data reuse [28].



Take the next step towards autonomous excellence

In conclusion, researchers provide a detailed overview of the main challenges related to obstacle detection and safety for automated and autonomous vehicles, and they agree that most of these problems can be addressed by using LiDAR monitoring in the infrastructure. Additionally, implementing LiDAR-based ITS can make a big difference in the less complex scenarios already today, e.g. by providing information and insights to traffic lights, to improve traffic flow and safety, this without being connected to vehicles.

LiDAR data represents outstanding and highly valuable data streams. With perception software, your systems can utilize auto-labeled data to enhance the overall performance without the need of annotation or training the system. The information can also be used for immediate actions like closing a road from vulnerable road users or to alert drivers and pedestrians. By integrating AI, this system not only provides real-time awareness but also optimizes operations over time, enhancing understanding of trends and patterns.

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