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UNCREWED GROUND VEHICLES FOR BUS MALFUNCTION DETECTION AND INFRASTRUCTURE SURVEILLANCE: EXPLORING THE OPERATIONAL APPLICABILITY AND CHALLENGES

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Summary: Public transportation plays a crucial role in mitigating the significant environmental and economic challenges posed by widespread private vehicle use, such as automobiles and motorcycles. In 2021, buses accounted for approximately 35% of passenger kilometers traveled in European Union countries through public transportation. This figure often doubles in developing nations, where buses are more cost-effective to implement and operate compared to other public transit systems. Ensuring proper bus operation while maintaining infrastructure safety is essential for efficient and reliable urban mobility.

Traditional inspection methods are labor-intensive, costly, and prone to human error, highlighting the need for innovative solutions. Uncrewed Ground Vehicles (UGVs) have emerged as cost-effective tools for automating and enhancing inspection processes while also serving as an efficient alternative to traditional surveillance methods. Although the initial investment may be substantial, UGVs offer long-term advantages, including reduced labor demands, improved surveillance accuracy, and scalable deployment, making them an appealing option for bus terminal operators.

This article explores the potential deployment of the Versatile Integrated Ground-based Intelligence and Logistics Autonomous Navigation Tool (VIGILANT) UGV for detecting bus malfunctions and monitoring infrastructure, with a focus on its capabilities, challenges, and broader implications.

VIGILANT is equipped with advanced technologies to enhance operational reliability and safety. A thermal camera allows the detection of abnormal motor temperatures, signaling potential overheating or malfunctions. Together with an optical camera, the surveillance capabilities are enhanced by identifying and tracking suspicious individuals, which could improve security at bus terminals. Autonomous navigation algorithms ensure safe and efficient operation in dynamic, crowded environments. Furthermore, the UGVs visual inspection capabilities allow for structural integrity assessments, while a hyperspectral camera allows the detection and identification of oil leaks - an essential indicator of potential mechanical failure. Together, these technologies provide a robust framework for improving the safety and reliability of bus fleets.

While UGVs offer promising capabilities, their deployment in bus terminals presents several challenges. Critical hurdles include ensuring reliable navigation in crowded environments, addressing cybersecurity threats, and gaining public acceptance. This study explores strategies to overcome these issues, including implementing robust path-planning algorithms, utilizing encrypted communication protocols, and conducting public awareness campaigns to facilitate the seamless integration of UGVs into existing security frameworks.

In conclusion, deploying UGVs like the VIGILANT framework offers a promising solution to enhance public transportation safety and efficiency. With capabilities such as detecting mechanical faults, monitoring infrastructure, and improving security, UGVs can address critical operational challenges. While initial costs and various challenges remain, a set of strategies can be applied to facilitate their integration. This study highlights the potential of UGVs to transform bus terminal operations and support sustainable urban mobility.