YOLOv9-Enabled Vehicle Detection for Urban Security and Forensics Applications

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Abstract—The integration of artificial intelligence (AI) techniques in vehicle detection holds significant promise, particularly in forensic and security domains. Leveraging object detection algorithms enables real-time monitoring of vehicles by competent authorities, aiding in continuous surveillance of roads and highways for various surveillance objectives. Additionally, it streamlines tasks such as identifying stolen vehicles, tracking suspects, and enforcing traffic regulations. Object detection technology also proves invaluable in forensic analysis, aiding criminal investigations and accident reconstructions. Furthermore, it enhances security by detecting aberrant behavior and potential threats at critical infrastructure sites. Concurrently, the remarkable advancements in unmanned aerial vehicles (UAVs) have led to their widespread application across diverse domains, including traffic monitoring and intelligent transportation systems. Equipped with high-resolution cameras, UAVs offer precise imagery for vehicle detection, facilitating swift responses to incidents. This study focuses on vehicle detection from aerial urban transportation images using YOLOv9 on a UAV platform, demonstrating the feasibility and efficacy of aerial analysis for efficient vehicle detection and timely alerts to competent authorities.

Keywords—*aerial monitoring, forensic investigation, YOLOv9, vehicle detection, UAV*

I. INTRODUCTION

Besides the numerous advantages of utilizing artificial intelligence techniques for detecting vehicles, there are notable forensic and security ramifications [1]. This technology enables competent authorities to conduct real-time monitoring of vehicles, leveraging object detection algorithms for continuous surveillance of roads and highways. Such capability is indispensable for various surveillance objectives, including monitoring traffic flow, detecting accidents, and identifying suspicious vehicles or activities [2]. Furthermore, it streamlines diverse tasks such as identifying stolen vehicles, tracking suspects, and enforcing traffic regulations [3]. For instance, integration of object detection with surveillance systems empowers law enforcement to swiftly pinpoint vehicles of interest and mount effective responses to incidents. In forensic analysis aspect, vehicle detection technology proves invaluable in criminal investigations and accident reconstructions. Surveillance footage processed through object detection algorithms yields crucial evidence by pinpointing vehicles present at the scene, tracing their movements pre- and post-incident, and reconstructing event timelines. Additionally, it serves as a tool for detecting aberrant behavior, such as unauthorized vehicles breaching restricted areas or deviating from typical traffic patterns, thereby bolstering security at critical infrastructure sites, border crossings, and sensitive locales [4]. Integration of object detection capabilities with other security systems enables automated detection of potential threats, including vehicles transporting suspicious objects or individuals. Security personnel can swiftly respond to security breaches by configuring alerts triggered by specific vehicle attributes or behaviors. Moreover, object detection algorithms contribute to streamlined traffic management by analyzing vehicle flow, identifying congestion hotspots, and optimizing traffic signals. Insights garnered from analyzing traffic patterns and trends empower authorities to implement measures that enhance overall road safety and mobility. Furthermore, collection of vehicle detection data presents opportunities for in-depth analysis, unveiling pertinent patterns, trends, and anomalies. This wealth of information can be harnessed to enrich predictive analytics, fortify security strategies, and optimize resource allocation for law enforcement and traffic management endeavors.

Given the remarkable advancements in unmanned aerial vehicles (UAVs) today, they have become increasingly prevalent across various academic research domains. Their applications span a wide spectrum, including traffic monitoring, vehicle detection, surveillance, mapping, and intelligent transportation systems [5, 6]. The affordability and versatility of UAV systems, coupled with their seamless integration into diverse applications, have significantly bolstered their popularity. Equipped with high-resolution cameras, UAV systems excel in capturing precise imagery within designated mission areas. Leveraging UAV technology in the development of intelligent transportation systems holds significant promise, particularly in areas such as traffic management, road safety, and transportation planning within conventional infrastructures [7]. Utilizing UAV systems to gather traffic imagery offers invaluable insights into traffic density, disruptions due to road construction, and traffic accidents, enabling proactive interventions to mitigate issues and enhance both pedestrian and vehicular routes. Additionally, UAV-enabled mapping facilitates the creation of smart traffic maps, empowering real-time data-driven decisions such as offering alternative routes during traffic congestion and swiftly addressing emergency situations related to security and public health. Furthermore, the real-time data acquired from UAVs can revolutionize security measures by enabling preemptive interventions against potential smuggling and security threats. Consequently, the abundance of real-time data afforded by UAV systems opens doors to innovative solutions, revolutionizing the field of traffic monitoring beyond the constraints of conventional data sources.

Detecting vehicles stands as a paramount focus within the field of computer vision, where numerous object detection algorithms prove instrumental. The landscape of object detection has evolved significantly with the advent of deep