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Crowd Behaviour Analysis for Public Safety Using Aerial Surveillance and Machine Learning Algorithms

Amit Joshi, K. Peermohamed
Riga Nordic University and BA School of Business and Finance, Sethu Institute of Technology

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[1]Amit Joshi, Lecturer and Researcher, Department of Computer Technologies and Natural Sciences, Riga Nordic University and BA School of Business and Finance, Riga, Latvia. Amit.joshi00008@gmail.com

[2]K. Peermohamed, Assistant Professor, Computer Science and Engineering, Sethu Institute of Technology, Kariapatti, Virudhunagar District, Tamil Nadu. peermohamed@sethu.ac.in

Abstract

The rapid evolution of unmanned aerial vehicles (UAVs) and machine learning technologies has revolutionized the field of crowd behavior analysis, offering innovative solutions to enhance public safety in large-scale events and urban environments. This chapter explores the integration of UAV-based aerial surveillance with advanced machine learning algorithms for real-time crowd monitoring, anomaly detection, and risk assessment. By harnessing the power of high-resolution imaging, environmental sensing, and predictive analytics, UAVs provide comprehensive insights into crowd dynamics, enabling proactive safety measures. The application of multimodal sensor fusion enhances the accuracy of crowd monitoring, while machine learning models detect potential threats, such as crowd surges, violent behavior, or medical emergencies, long before they escalate. The chapter also delves into the challenges of storing and managing vast amounts of UAV-generated data, highlighting the need for efficient data processing systems and secure cloud-based storage solutions. As UAV and sensor technologies continue to advance, their integration with cutting-edge AI-driven decision-making frameworks promises to transform urban crowd management and public safety protocols. This research offers a forward-looking perspective on the potential of UAVs and machine learning in mitigating risks and optimizing crowd management strategies in complex environments.

Keywords: Unmanned Aerial Vehicles (UAVs), Crowd Behavior Analysis, Machine Learning, Anomaly Detection, Risk Assessment, Multimodal Sensor Fusion.

Introduction

Urban environments have experienced unprecedented growth in both population and event attendance, leading to increasingly complex challenges in managing public safety during large gatherings [1]. Traditional methods of crowd monitoring, such as fixed surveillance cameras and on-the-ground security personnel, often lack the ability to provide a comprehensive, real-time view of crowd behavior [2]. As such, there is a growing need for innovative approaches that can improve situational awareness, detect emerging threats, and enhance overall crowd management [3]. Unmanned aerial vehicles (UAVs) equipped with advanced imaging systems and sensors present a transformative solution to these challenges [4]. These aerial platforms provide a dynamic and

scalable method for monitoring crowds from various angles, allowing for a more holistic understanding of crowd behavior across large, complex environments [5].

The integration of UAVs with machine learning algorithms has the potential to revolutionize how crowd dynamics are analyzed and managed in real-time [6]. Machine learning techniques, such as anomaly detection and pattern recognition, enable the automated identification of unusual crowd behaviors that could signal potential risks [7]. For instance, sudden surges in crowd density, erratic movement patterns, or the emergence of hostile actions can be detected before they escalate, enabling security personnel to respond proactively rather than reactively [8]. This real-time detection capability is crucial in preventing incidents such as stampedes [9], violence, or medical emergencies, ensuring that appropriate measures are taken swiftly to mitigate potential harm [10].

As UAVs become increasingly integrated into public safety operations, the role of multimodal sensor fusion will play a critical part in enhancing the precision and reliability of crowd monitoring systems [11]. UAVs are equipped with a range of sensors, including thermal, infrared, and LiDAR, each offering unique insights into crowd behavior under different conditions [12]. For example, thermal imaging allows for the detection of heat signatures, which is particularly useful in low-light environments, while LiDAR can generate 3D models of crowd density and movement [13]. The fusion of these various sensor types enables a more comprehensive analysis [14], providing security teams with richer data to make better-informed decisions about crowd control and risk mitigation [15].