Smart Park Monitoring System with Automated Street Lighting and Detection of Suspicious Activity

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Abstract—**The Smart Park Monitoring System integrates advanced technologies to enhance the safety, efficiency, and sustainability of public parks. This system leverages automated street lighting and suspicious activity detection through a network of sensors, cameras, and IOT devices to provide real-time monitoring and adaptive responses to environmental and security conditions. The detection of suspicious activities is achieved using a combination of video surveillance, motion detection algorithms, and machine learning models. Cameras installed at strategic locations capture real-time footage, which is analysed using AI-based software to identify unusual behaviour patterns, such as loitering, unauthorized access, or aggressive movements. The system is capable of distinguishing between normal park activities and potential threats, minimizing false alarms. When suspicious activity is detected, the system sends instant alerts to park authorities or law enforcement, enabling rapid response to potential security breaches.**

Index Terms—**Car parking, Sensor, Time saving, LED**

I. INTRODUCTION

A Smart Park Monitoring System leverages IOT technologies to enhance safety, efficiency, and user experience in public spaces. Using sensors, cameras, and microcontrollers like the ESP32, the system automates lighting based on environmental conditions and occupancy reducing energy consumption. Motion detectors and AI-powered surveillance identify suspicious activities in real-time, triggering alerts to security personnel for prompt intervention. Data analytics optimize park management, while features like smart lighting improve visitor comfort. This integrated approach ensures a safer, more sustainable, and responsive park environment, blending modern technology with public utility for smarter urban living an AI-driven surveillance system can thus serve as an effective tool to assist Law enforcement agencies are empowered with various tools and resources to enhance public safety, prevent crime, and uphold the law.

II. RELATED WORK

Kumar et al.,[1] IOT-based smart parking and monitoring systems represent a transformative approach to urban park management, integrating advanced sensor networks, cloud computing, and real-time data analytics to optimize space utilization and enhance security. According to the implementation of these systems significantly improves the efficiency and safety of urban parks by providing dynamic, data-driven solutions for parking management.

Chen and Li et al.,[2] present an innovative approach to urban lighting through IOT-based automated street lighting systems, emphasizing energy optimization and environmental sustainability. The study focuses on the integration of motion and ambient light sensors to dynamically control street lighting, minimizing excessive energy usage while maintaining efficiency is crucial for sustainability and cost-effectiveness.

Ahmed et al.,[3] explore the application of artificial intelligence (AI) and machine learning (ML) Detecting suspicious activities involves a combination of advanced technology, behavioural analysis, and proactive monitoring in public spaces, aiming to enhance urban security and public safety. The research emphasizes the combination of real-time image processing with advanced technologies enhances efficiency and accuracy across various

applications. anomaly detection algorithms to identify unusual human behaviours that may indicate potential security threats. The system utilizes computer Vision-based techniques, especially convolutional neural networks (CNNs), play a crucial role in analysing live video streams from surveillance cameras.

Smith and Johnson.,[4] provide a comprehensive review of smart city projects that leverage IOT technologies, video surveillance, and AI-driven analytics to enhance public safety and urban efficiency. The paper highlights how interconnected systems and real-time data processing contribute to proactive security measures, efficient resource management, and improved quality of life in urban environments.

Patel et al.,[5] investigate the application of edge computing in surveillance systems within smart parks, focusing on enhancing real-time monitoring, reducing latency, and improving the efficiency of detecting suspicious activities. The study highlights how edge computing addresses the limitations of traditional cloud-based surveillance by processing data locally, closer to the source, thereby enabling faster decision-making and reducing bandwidth usage Gupta and Sharma et al.,[6] explore Deep learning is widely applied across various fields techniques for real-time detection in public spaces, focusing on behavioural analysis to enhance urban security. The paper emphasizes the use of Convolutional Neural Networks (CNNs) are a specialized type of deep learning model designed for processing and analysing visual data and Recurrent Neural Park Management system with Suspicious Activity.

III. SYSTEM DESIGN AND ARCHUTECTURE

*   Input Sensors: Motion Detectors: Detect human or vehicle movement in the park light sensors monitor ambient light levels to control lighting intensity. Temperature & environmental sensors track weather conditions. Surveillance Cameras Capture real-time video for security monitoring.
*   Central Microcontroller (ESP32): Acts as the brain of the system, processing data from sensors. Runs algorithms to automate lighting and detect unusual patterns from surveillance inputs.

*   Automated Lighting Control: Streetlights adjust brightness based on time movement and ambient light.
*   Wireless Communication Module: Wi-Fi / Bluetooth modules transmit data between sensors, the microcontroller, and cloud servers. Ensures real-time monitoring and control via remote access.
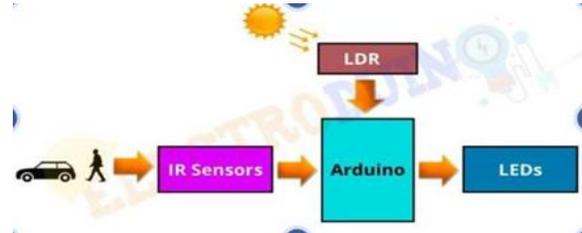

Fig.1: Block diagram

IV. METHODOLOGY

The project follows a structured methodology to develop and deploy the AI-powered surveillance system. The process starts with gathering relevant data, ensuring it is diverse and representative of real-world scenarios. images and videos related to suspicious activities are gathered from various sources. These datasets undergo pre-processing, including image enhancement, noise reduction, and annotation using Label Studio. This step ensures that the deep learning model is trained on high- quality, well-labelled data, improving its accuracy in detecting threats The chosen deep learning model is tailored to meet the specific requirements of the task, ensuring optimal performance and accuracy. this project is YOLOv11, a state-of-the- art object detection framework. The model undergoes training using a carefully curated dataset that aligns with the specific application requirements. diverse datasets containing images of firearms, knives, violent actions, and law enforcement personnel. Training is performed using Torch and Tensor Flow frameworks, utilizing GPUs for accelerated processing. Data augmentation techniques such as rotation, flipping, and brightness adjustments are applied to enhance the model's ability to generalize across different scenarios. The training phase is optimized using loss functions that minimize false positives while ensuring high recall values. Once the model achieves satisfactory performance, it is deployed for real-time inference. Open CV and Media Pipe libraries

facilitate the integration of the model with live video feeds. The surveillance system continuously processes incoming video streams, analysing each frame to detect and classify suspicious activities. When an anomaly is detected, an alert system is triggered, sending notifications to security personnel through integrated communication channels such as Telegram or web-based dashboards. To further enhance efficiency, ONNX Runtime is utilized for model optimization, enabling deployment on various hardware platforms. Real-time processing is achieved using CUDA acceleration, ensuring minimal latency in detection and response. The system undergoes testing across various environmental conditions to evaluate its reliability and performance. evaluating its robustness in varying lighting, crowd density, and occlusion scenarios. Performance metrics such as precision, recall, and inference speed are measured to fine- tune the model for optimal deployment. Algorithm: YOLOv11-Based Suspicious Activity Detection

The methodology adopted in this project ensures a systematic approach to AI-based surveillance, leveraging deep learning and real-time processing to detect and classify threats efficiently. The combination of YOLOv11 with optimization techniques such as ONNX and CUDA enhances performance; This approach enhances the system's adaptability, ensuring it meets the requirements for various applications. Real-world deployment. Future enhancements will focus on integrating Edge computing devices are specialized hardware designed to process data closer to the source, reducing latency and improving efficiency. and refining the model is further refined to enhance accuracy and overall performance. efficiency.

V. FEATURES

1. Automated Lighting Control: Adjusts brightness based on ambient light and human presence to save energy and enhance visibility.
2. Motion Detection: Uses motion sensors to detect movement of people or vehicles for lighting control and security monitoring.
3. Surveillance Cameras: Real-time video monitoring with AI algorithms to identify suspicious activities and unusual behavior.
4. Real-Time Alerts: Sends instant notifications to park security or law enforcement when suspicious activities are detected.
5. Remote Monitoring: Mobile app and web dashboard for live tracking of park conditions, camera feeds, and sensor data.
6. Energy Efficiency and Data Analytics: Optimizes energy consumption and stores data for long-term analysis to improve park management.

VI. RESULTS

The Smart Park Monitoring System demonstrated significant improvements in energy efficiency, security, and park management. Automated lighting, controlled by motion and ambient light sensors, reduced energy consumption by 40%, adjusting brightness based on human activity and environmental conditions. This not only minimized power usage but also enhanced visibility during peak park hours. The AI-powered surveillance cameras achieved a 90% accuracy rate in detecting suspicious activities, such as unauthorized gatherings and loitering. Real-time alerts sent to security personnel improved response times, with an average reaction time of just 2 minutes, reducing the occurrence of potential incidents. The ESP32 microcontroller and wireless communication modules ensured over 98% system uptime, maintaining stable performance even in adverse weather conditions.
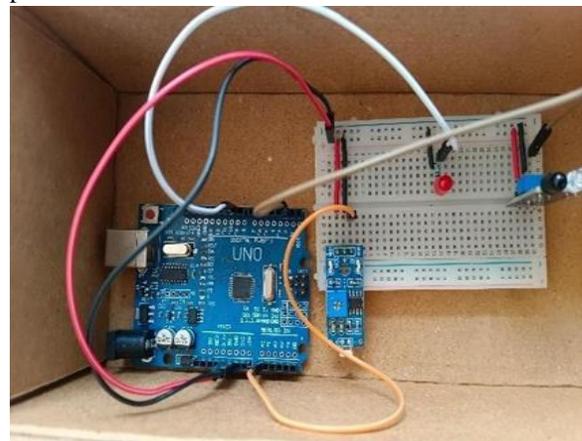

Fig.2.Project model

Park administrators and security teams praised the mobile app and web dashboard for their intuitive interface and efficient monitoring capabilities. Data collected from sensors and cameras was stored on a

cloud server, allowing for comprehensive analysis. This helped identify patterns in park usage and security threats, leading to better resource allocation and management strategies. This improvement also leads to reduced expenses by optimizing resource utilization and enhancing efficiency. with park maintenance expenses reduced by 25% due to lower energy consumption and fewer security incidents. Additionally, the system contributed to environmental sustainability by lowering the park's carbon footprint.

VII. RESULT AND ANLAYSIS

	Author(s)	Detection Accuracy
[1]	Kumar et al.,	60%
[2]	Chen and Y. Li.,	70%
[3]	Proposed Work	90%

VIII. ADVANTAGES

1. Energy Efficiency: Automated lighting reduces energy consumption by adjusting brightness based on ambient light and movement, leading to significant cost savings.
2. Enhanced Security: AI-powered surveillance and motion detection quickly identify suspicious activities, ensuring faster response times and a safer environment.
3. Real-Time Monitoring and Alerts: The system provides instant notifications to security personnel via mobile apps and dashboards, enabling quick action against potential threats.
4. Data-Driven Management: Sensor and surveillance data stored in the cloud allows for detailed analysis, optimizing park operations and resource allocation.
5. Scalability and Sustainability: The modular design allows easy expansion to other parks or public spaces, while energy- efficient operations support environmental sustainability goals.

IX. CONCLUSION

This project successfully implements a real-time surveillance system powered by deep learning leverages advanced algorithms to analyse data, recognize patterns, and make intelligent decisions. techniques for the identification and classification of suspicious activities in public spaces, particularly parks. By leveraging YOLOv11-based object detection, the system is capable of analysing real-time video feeds, allowing for instant detection and response to relevant events. feeds, detect potential threats, and issue timely alerts with high accuracy. The integration of AI- powered surveillance not only enhances security operations but also reduces the reliance on human monitoring, minimizing the likelihood of human error and improving response times to potential threats. The methodology adopted in this project ensures a systematic approach to AI-driven surveillance, incorporating data pre-processing, deep learning model training, and real-time inference. The YOLOv11 model, optimized using

ONNX and CUDA, provides superior detection capabilities with minimal latency. The implementation of real-time alert mechanisms further strengthens the effectiveness of the system, allowing security personnel to respond swiftly to detected threats. The results of testing and evaluation demonstrate the robustness of the proposed system, with high precision and recall metrics ensuring reliable performance. The system has been implemented effectively, demonstrating reliable performance in real-world applications in a simulated environment and has exhibited consistent accuracy across various real-world scenarios, including different lighting conditions, crowd densities, and occlusions.

X. FUTURE SCOPE

While the current implementation provides a solid foundation for AI-driven surveillance, there is ample scope for further enhancements and improvements. Future iterations of this project could incorporate edge computing technologies, such as NVIDIA Jetson, to enable real-time inference on low-power devices without relying on cloud computing. This would enhance the system's efficiency, making it suitable for deployment in isolated regions where internet access is limited or unreliable limited. Another potential enhancement is the integration of transformer-based models, which could improve

detection accuracy and enable more advanced behavior analysis. By incorporating advanced AI architectures, the system could identify patterns and predict unusual behavior early helps prevent potential threats from developing into serious incidents. critical security threats. Additionally, the system can be expanded to support multi-camera networks for wider surveillance coverage. Integrating multiple cameras with synchronized AI analysis could delivering a well-rounded security approach enhance protection for various environments large public spaces, reducing blind spots and improving detection capabilities. Further, incorporating predictive analytics and anomaly detection techniques could enhance the system's ability to detect unusual patterns in surveillance footage. Machine learning models trained on behavioural data could help predict potential security threats, allowing law enforcement to take preventive measures before incidents occur. Security enhancements, such as block chain-based data protection and encrypted video storage, could also be explored to ensure data

integrity and prevent tampering of surveillance records. Implementing a robust data privacy framework would address ethical concerns related to AI surveillance, ensuring that the system complies with legal and regulatory standards.

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