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A DEEP LEARNING BASED-EFFICIENT FIREARMS MONITORING TECHNIQUE FOR BUILDING SECURED SMART CITIES

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ABSTRACT

Violence remains a pervasive issue in modern society, with firearm-related incidents posing a significant threat to public safety and challenging law enforcement agencies worldwide. Despite advancements in civilization, firearms continue to be a common means of violence, particularly in urban and semi-urban areas. While CCTV-based surveillance systems are widely deployed for crime prevention and monitoring, traditional human-based monitoring is both resource-intensive and prone to errors. To address these limitations, this project explores the application of deep learning techniques for automated firearm detection, specifically focusing on guns. The system leverages advanced object detection methods such as Faster Region-Based Convolutional Neural Networks (Faster R-CNN) and EfficientDet architectures to accurately identify guns and human faces in surveillance footage. Additionally, ensemble methods—including Non-Maximum Suppression, Non-Maximum Weighted, and Weighted Box Fusion—are implemented at the post-processing stage to enhance detection accuracy. Through comprehensive comparative analysis, this study demonstrates how integrating multiple detection approaches improves overall performance. The proposed system aims to assist law enforcement by enabling quicker response and proactive intervention, thereby contributing to public safety and the reduction of firearm-related violence.

Keywords: Deep learning, gun detection, firearm detection, surveillance, object detection, Faster R-CNN, EfficientDet, ensemble methods, Non-Maximum Suppression, Weighted Box Fusion, public safety, automated monitoring, violence prevention, face detection, CCTV analysis.

I.INTRODUCTION

While the COVID-19 pandemic has dominated global attention due to its widespread impact and death toll, other persistent causes of mortality—such as road accidents and gun-related violence—continue to claim countless innocent lives every year. Among these, firearm-related deaths have emerged as a major public health concern worldwide. Historically, guns played a pivotal role in warfare, particularly during the 19th century American Civil War, and have since become standard equipment for law enforcement and military forces across nations. However, firearms are increasingly being misused by criminals and rioters to instill fear, commit crimes, and assert power. The issue of gun violence is particularly acute in the United States, where mass shootings have become a distressingly frequent occurrence. In 2015 alone, over 36,000 Americans lost their

lives to gun violence. Globally, more than 1.4 million people were killed by firearms between 2012 and 2016. Notable mass shootings in recent history include the 1987 Hoddle Street Massacre in Melbourne, the 2019 Christchurch mosque shootings in New Zealand, the 2017 Quebec City mosque shooting in Canada, and the devastating 2011 Norway attacks, which claimed 92 lives. Gun violence is not confined to Western nations; countries like Israel and India have also experienced tragic incidents, such as the 1972 Lod Airport Massacre and the 2008 Mumbai attacks, respectively.

The definition of a mass shooting varies across jurisdictions. According to the FBI, a mass murder involves four or more people killed in a single incident without a cooling-off period, while U.S. Public Law 112–265 defines "mass killings" as three or more deaths in a single event at a public location. Generally, mass shootings are characterized by incidents where three or more individuals are killed or injured in a confined area over a brief time span, excluding the perpetrator(s). Given the increasing frequency and severity of such events, there is an urgent need for advanced surveillance and detection systems. Automating the identification of firearms in public spaces through intelligent technologies can significantly aid law enforcement agencies in preventing and responding swiftly to such threats.

II.LITERATURE REVIEW

With the advancement of smart city technologies, ensuring public safety through intelligent surveillance has become a high priority. Among the many challenges, the real-time detection and monitoring of firearms is critical in preventing crimes and ensuring rapid emergency response. Traditional surveillance systems often rely on manual monitoring or simple motion detection, which are neither scalable nor reliable in high-risk environments. Deep learning has emerged as a powerful tool for automating object detection tasks, especially for identifying weapons such as firearms in video feeds and images.

1. Traditional Surveillance and Firearm Detection Techniques

Earlier firearm detection systems were largely based on motion detection, manual monitoring, or rule-based approaches. These systems are limited by high false alarm rates and poor accuracy under complex environmental conditions such as occlusion, lighting variation, and crowd density. According to [Chen et al., 2015], manual review of surveillance feeds is not only time-consuming but also prone to human error, especially in high-volume surveillance zones such as airports and train stations.

2. Deep Learning for Object Detection

Deep learning, particularly Convolutional Neural Networks (CNNs), has revolutionized object detection and image classification. Models like **YOLO (You Only Look Once)**, **Faster R-CNN**, and **SSD (Single Shot MultiBox Detector)** have demonstrated real-time performance and high accuracy in detecting small and concealed objects, including firearms. [Redmon et al., 2016] introduced YOLO as a unified model capable of processing images at high speed, making it suitable for real-time surveillance in smart cities.

3. Weapon Detection Using Deep Learning

Several recent works focus specifically on firearm detection using deep learning. [Olmos et al., 2018] proposed a CNN-based approach to identify guns in CCTV footage, achieving notable accuracy even in cluttered environments. Another study by [Dang et al., 2019] used deep transfer learning with ResNet and MobileNet to classify various types of firearms in surveillance videos. These models outperform traditional image processing techniques and offer scalability for deployment across smart city infrastructure.

4. Smart Surveillance Systems in Smart Cities

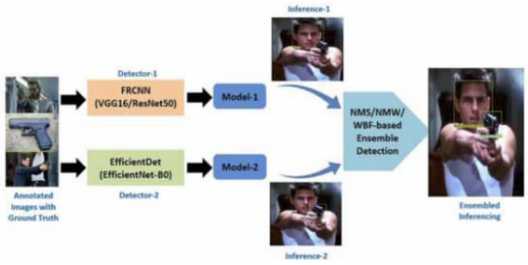
Smart cities leverage IoT and AI technologies to build intelligent systems for traffic control, public safety, and emergency response. Firearm detection, as a component of smart surveillance, integrates with other smart city systems such as law enforcement alerts, access control, and incident tracking. [Gaurav et al., 2021] discuss the role of AI-driven surveillance in reducing crime rates and improving law enforcement response times through real-time alerts and visual analytics.

III.PROPOSED METHODOLOGY

This project introduces an ensemble-based detection strategy aimed at identifying human faces and firearms—including revolvers, pistols, and handguns—in static images or video frames. The system utilizes multiple deep learning-based object detection architectures to enhance accuracy and robustness. The core detection models employed include **Faster Region-Based Convolutional Neural Networks (Faster R-CNN)** with **ResNet-50** and **VGG-16** as backbone feature extractors. In parallel, the **EfficientDet** architecture, leveraging **EfficientNet-B0** as its backbone, is implemented for comparative analysis and integration into the ensemble framework. To further refine detection outcomes, a **stacked ensemble configuration** is adopted. After individual model predictions are generated, a post-processing phase is initiated to combine outputs using three distinct bounding box aggregation techniques:

Weighted Box Fusion (WBF)

These methods are employed to consolidate overlapping bounding boxes from multiple detectors into a single, precise detection for each object. The **novelty** of this work lies in its demonstration that combining **Faster R-CNN** and **EfficientDet** architectures within an ensemble framework significantly enhances object detection performance—**without requiring additional training** of the base models. The ensemble scheme capitalizes on the complementary strengths of each detection model, yielding more accurate and reliable identification of firearms and faces. The term “efficient” in the paper’s title reflects this key contribution: the ability to **improve detection accuracy using existing pretrained m**



IV.CONCLUSION

This project has demonstrated the effectiveness of a deep learning-based framework for the detection of human faces and firearms in surveillance footage. Through extensive empirical evaluation, it has been observed that the Weighted Box Fusion (WBF)-based ensemble detection scheme significantly enhances detection accuracy compared to individual models. A key observation from the study is the trade-off between model size and performance. The Faster R-CNN (FRCNN) architecture, while accurate, produces a large model file (~108 MB) and has a noticeable impact on frame-per-second (FPS) performance within ensemble configurations. In contrast, EfficientDet-B0 offers a lightweight alternative (~16 MB), making it a more suitable candidate for real-time surveillance systems with resource constraints. To address limitations in speed and model size, future implementations can explore lightweight ensemble strategies by using EfficientDet with varying EfficientNet backbones, ensuring both efficiency and accuracy. Furthermore, even if the individual detection models are relatively weak, their combination in an ensemble enhances overall performance due to the diversity of detection perspectives. The findings underscore the potential of integrating this approach into CCTV-based monitoring systems, transforming them into intelligent surveillance solutions capable of proactive threat detection. Ultimately, the goal of this work is to contribute to public safety and foster a more secure environment for communities.

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