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Weapon D - A Hybrid Approach for Detecting Weapons in Dark Environments Using Deep Learning Techniques

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Weapon detection, a crucial part of modern security is vital for public safety and strengthening security measures. Accurately spotting weapons in different places helps law enforcement, surveillance, and security. The ongoing improvements in weapon detection technologies not only boost preventive actions but also help respond quickly in emergencies, reducing risks and improving readiness. These technologies greatly assist law enforcement in identifying threats early and taking action promptly to keep the public safe and protect important places. Our proposed

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system suggests YOLOv7 with brightening algorithms, specially designed to detect weapons in low-light or nighttime situations. This shift from the existing to the proposed system marks a substantial improvement, addressing the challenges of nighttime weapon detection. This breakthrough not only enhances the scope of security measures but also underscores the adaptability of technology to real-world challenges. By catering to challenging dark settings, this advancement strengthens the foundation of public safety initiatives, offering a proactive approach to mitigating potential threats in diverse environments.

Keywords: Weapon detection; security measures; law enforcement; surveillance; YOLOv7; brightening algorithms; nighttime detection.

1. INTRODUCTION

The "WeaponD (Weapon Detection)" project aims to develop a robust and efficient system aimed at enhancing public safety and security through the development of an advanced system capable of detecting weapons in images and videos in real-time. In today's world, where the threat of firearm related incidents looms large, the need for proactive measures to identify and prevent potential threats has never been more crucial. Leveraging state-of-threat deep learning techniques and computer vision algorithms, this project seeks to address these concerns by providing a reliable and efficient weapon detection solution. The main goal of the project is to develop a weapon detection system that is both flexible and scalable, so that it can be easily included into other security frameworks, such as surveillance systems, law enforcement operations, and public safety programs. The system uses deep learning to automate the process of identifying firearms and other dangerous objects, allowing law enforcement to react quickly to possible threats and take preventative action to reduce risks.

The weapon detection system has a number of important aspects that improve its utility and efficacy. These include adaptive brightness and contrast modifications to maximize image quality for precise detection, support for both image and video inputs, and real-time processing capabilities.

In order to gather multi-scale data and enhance detection performance, the system also integrates sophisticated feature extraction methods including Extended Efficient Layer Aggregation Networks (E-ELAN) and Feature Pyramid Networks (FPN). The device can detect firearms in both bright and dark conditions because to its deep learning-based object detection algorithms, which enables law enforcement to respond promptly and protect public safety. All things considered, the project is a major advancement in the creation of intelligent security systems that successfully handle contemporary issues.

2. LITERATURE REVIEW

The literature survey for the WeaponD project showcases a diverse range of studies focusing on weapon detection using deep learning techniques.

It was announced that YOLO V3 would be implemented specifically for smart surveillance systems. The importance of real-time detection capabilities in improving security measures is highlighted by this work [1].

An alternative method for addressing the difficulties associated with weapon detection in security and video surveillance scenarios involved the combination of convolutional neural networks (CNN) and YOLO-v5s. This method highlights the crucial harmony between speed and accuracy needed for efficient surveillance applications [2].

The presentation showcased a robust gun detection system that utilized YOLOv3, showcasing significant progress in object detection technologies for security objectives. This study emphasizes how crucial reliable detection algorithms are to maintaining the security and safety of monitoring environments [3].

A weapon identification system based on images and employing YOLO algorithms in real- time was presented. The practical applications of deep learning models in actual surveillance scenarios are highlighted in this study, providing encouraging directions for enhancing security protocols [4].

An analysis was carried out on the use of deep learning methods particularly for surveillance video weapon identification. The potential of deep learning algorithms to improve the efficacy and efficiency of surveillance systems is highlighted by this work [5].

Robust weapon detection in dark environments using Yolov7-Dark Vision. Digital Signal Processing, 145, 104342." indicates a project focused on enhancing weapon detection capabilities in low-light conditions using Yolov7-DarkVision technology. This research addresses critical security concerns by proposing a robust solution for identifying weapons in dark environments, contributing to advancements in digital signal processing techniques for enhanced security applications. The study published in Digital Signal Processing highlights the significance of leveraging state-of-the-art technologies to address real-world challenges in security surveillance and threat detection [6].

3. PROPOSED SYSTEM

The proposed strategy combines the YOLOv7 deep learning architecture with a brightening algorithm to improve the identification of weapons at night or in low-light scenarios. This integration improves the precision and resilience of weapon detection, particularly in tough illumination settings, by combining modern image processing approaches and using YOLOv7's capabilities. These breakthroughs provide vital insights for surveillance and security, improving the performance of detection systems in a variety of real-world contexts.

3.1 Deep Learning Model YOLOv7

A major breakthrough in real-time object detection has been made with YOLOv7, an extension of the You Only Look Once (YOLO) family of object detection models. Building on the characteristics of its predecessors, YOLOv7 is renowned for its speed and precision, providing improved performance in a wide range of applications. Without sacrificing detection accuracy, YOLOv7 achieves exceptional efficiency by using a single neural network to forecast bounding boxes and class probabilities straight from entire photos in a single evaluation. Its streamlined architecture allows for quick inference, which makes it appropriate for applications like robotics, autonomous driving, and surveillance that need for quick processing. Furthermore, YOLOv7 facilitates the real-time detection of an extensive variety of objects. YOLOv7 remains a mainstay due to its resilience and adaptability.

3.2 Image Brightening Techniques

Especially in difficult lighting situations, brightening algorithms are crucial for improving visibility and image quality. These techniques enhance the general clarity and detail of images by modifying brightness and contrast, mitigating noise via Gaussian blur, standardizing pixel values, and fine-tuning gamma levels.

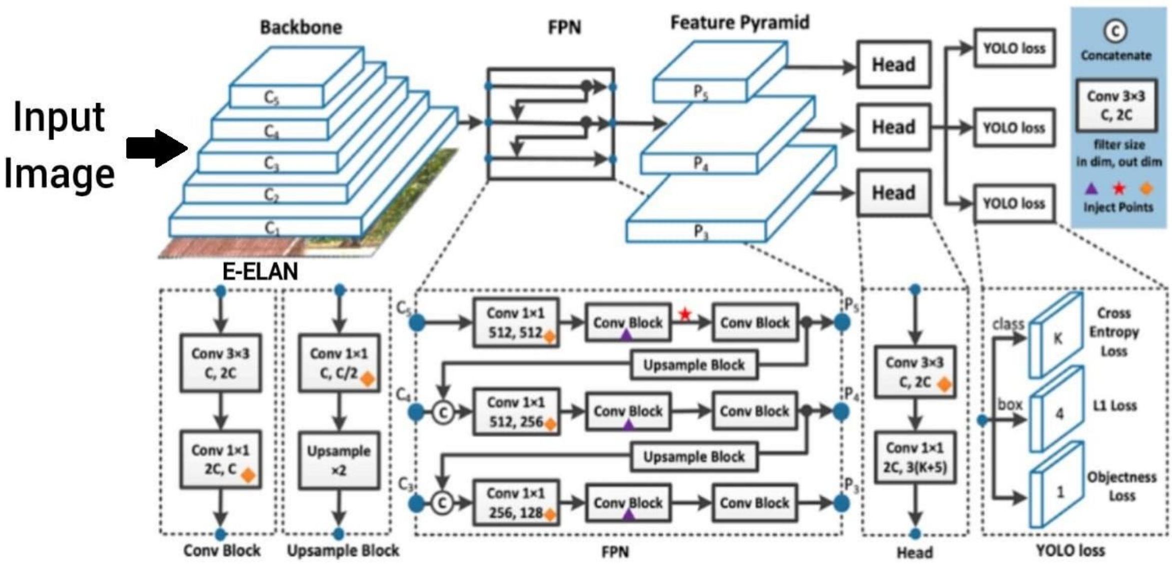

Fig. 1. Architecture of YOLOv7

By highlighting significant visual characteristics, its application helps computer vision tasks like object recognition and surveillance achieve higher levels of detection and analysis accuracy.

3.2.1 Gamma adjustment

A basic method in image processing for adjusting the brightness and contrast of digital images is gamma correction. It entails adjusting the gamma value, which regulates how an image's pixel values and corresponding displayed brightness are related. An image's overall brightness can be increased or decreased by varying this gamma value without materially changing the image's color balance. This method works especially well in situations where there are contrasts in illumination, like dimly lit areas or dramatic scenes. While maintaining the overall quality of the image, gamma modification can successfully increase the visibility of details in dark areas.

Furthermore, by making objects more visible in difficult lighting situations, gamma modification is essential for optimizing the effectiveness of object detection algorithms.

3.2.2 Contrast and brightness

Techniques for adjusting brightness and contrast play a vital role for improving weapon visibility in dimly lit or dark areas. It is possible to enhance the clarity and definition of weapon shapes and features by varying the contrast, which amplifies the difference in intensity between the brightest and darkest regions of an image. Contrarily, brightness adjustment makes it possible to change the image's overall luminance, which can help highlight details that might be hidden by darkness. These modifications are essential for maximizing weapon identification systems like YOLOv7 performance in difficult situations.

3.2.3 Gaussian blur

Gaussian blur is a method that is used to improve image quality prior to weapon identification. It functions by convolving the image using a Gaussian kernel, which efficiently reduces high- frequency noise while maintaining characteristics that are important for identification. By lessening the effect of tiny fluctuations in pixel intensity brought on by noise or distortions, this enhances the resilience of the model. Gaussian blur works especially well in low light conditions where atmospheric interference or sensor noise may deteriorate the clarity of the image. It makes it easier for the YOLOv7 model to identify weapons more accurately by reducing sharp edges and curves. Additionally, Gaussian blur serves as a regularization technique, preventing overfitting by smoothing out fine details.

3.2.4 Normalization

In order to improve an image's contrast and dynamic range and make analysis and display simpler, normalization is essential. Normalization is the process of bringing an image's pixel values to a standard range, usually between 0 and 1. This provides consistency between images despite changes in illumination or sensor characteristics. The images are better overall as a result of this standardization procedure, which also makes them more appropriate for further analysis tasks like object detection or categorization. Furthermore, normalization aids in reducing problems caused by irregular lighting or noise from sensors, which might impair the interpretability of the pictures. In general, normalization is a preprocessing technique that improves an image's visual quality and consistency, making it easier to analyze and interpret the data in a variety of applications.

3.3 Dataset Details

The YOLOv7 model is trained using the COCO dataset, a common object detection benchmark that covers a large number of item categories. Next, a custom handgun dataset devoted to weapon detection is used to further refine or train the pre-trained model. The process of fine-tuning improves the model's ability to accurately and precisely detect firearms, including rifles and handguns. As such, the model's focus is on weapon detection rather than a wide variety of items. Because of its customized training methodology, the model is optimized to identify weapons in a variety of circumstances, which makes it appropriate for security and surveillance applications where weapon identification is crucial.

3.4 YOLOv7 Integration with Brightening Techniques

The initial input for the Weapon detection comes from a variety of sources, including images and videos. The system creates dark frames by preprocessing individual frames it receives as input, whether it is an image or a video. Preprocessing techniques include

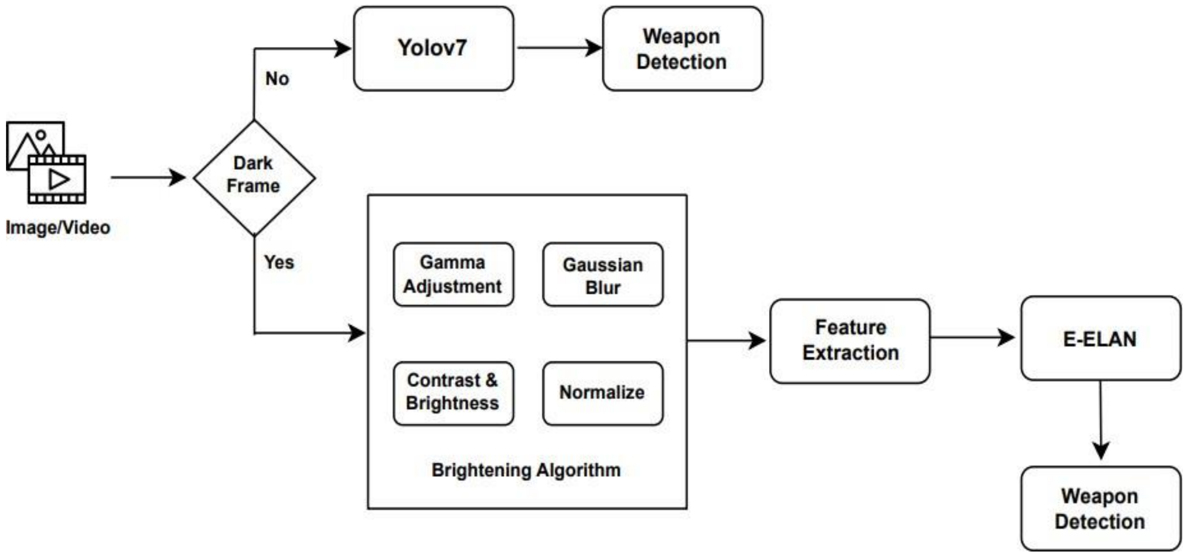

Fig. 2. Architecture of YOLOv7 with Brightening Techniques

brightness/contrast enhancement, which improves image clarity through the use of algorithms like gamma correction and normalization. This leads to improved weapon detection. Furthermore, to minimize noise and improve feature extraction in the dark frames, noise reduction techniques such as Gaussian blurring are used.

The Feature Pyramid Network (FPN) technique is used for feature extraction following preprocessing. By facilitating the extraction of relevant features from the improved images, FPN improves the model's capacity to recognize important patterns and attributes associated with weapons. Moreover, multi-scale features that are collected from the images are aggregated using the Extended Efficient Layer Aggregation Network (E-ELAN). This procedure contributes to more thorough feature representation and increased detection accuracy by helping to capture and synthesize data across various scales.

The system then moves on to the weapon detection phase, where it makes use of the features that have been processed and combined to find weapons in the original input picture or video. The system can efficiently identify and categorize firearms contained in the input data by integrating advanced detection algorithms with the enhanced picture characteristics extracted using FPN and E-ELAN. Preprocessing, feature extraction, and detection stages are all included in this fully-inclusive weapon detection method, which produces a reliable system that can reliably identify guns in a range of scenarios and environments [7-10].

4. RESULTS AND DISCUSSION

The performance of the Weapon detection was assessed using a collection of images with various backdrops, lighting conditions, and weapon types. The testing findings show that the suggested method is capable of reliably identifying firearms in practical situations.

The YOLOv7-based detection model demonstrated strong performance in a variety of settings, identifying weapons like handguns and rifles with a high accuracy. The incorporation of brightening methods, such as gamma modification, normalization, Gaussian blur, and contrast and brightness improvements, greatly improved the model's capacity to identify firearms in difficult lighting situations, including dimly lit areas or at night.

The practical implementation of the WeaponD system presents considerable opportunities for enhancing the current security framework, promoting proactive identification of threats, and expediting the reaction to possible security breaches. It is anticipated that more improvements in the system's performance and broader applicability across a range of domains, such as law enforcement, border control, and critical infrastructure protection, will come via continued training on a variety of datasets and system optimization [11-15].

4.1 Output Screens

Fig. 3. Handgun detected in an Image

Fig. 4. Handgun detected in a Video

Fig. 5. Enhanced image visualization: Dark frames and weapon detection

5. CONCLUSION

When combined with brightness algorithms, YOLOv7 has greatly enhanced weapon detection performance over earlier versions. This improvement guarantees more trustworthy threat identification. Brightening techniques are included into the detection pipeline so that even in low light or at night, the system is capable of detecting firearms.

The project's conclusions can be used to improve security protocols in a variety of settings, such as public safety, law enforcement, and video surveillance. This will lead to better situational awareness and proactive threat identification. It contributes significantly to the fields of computer vision and security technology by offering a dependable method of handgun detection in difficult illumination conditions.

6. FUTURE SCOPE

Enhanced Image Processing Techniques: Continued research and development in image processing techniques, such as improved feature extraction algorithms and deep learning architectures, could further enhance the system's accuracy and reliability in weapon detection, especially in challenging environments.

Real-time Detection for Security Purposes: The future scope involves refining the system's algorithms and optimizing hardware infrastructure to achieve real-time weapon detection, enabling prompt response to security threats and enhancing overall situational awareness in critical environments.

Incorporating the Model in CCTV Cameras through IoT: Integrating the weapon detection model with CCTV cameras through IoT frameworks opens up possibilities for real-time live detection of weapons in surveillance scenarios.

Accurate Results with Future YOLO Versions: Continuous advancements in object detection algorithms, such as future versions of YOLO, hold the promise of delivering even higher accuracy and efficiency in weapon detection. By leveraging these improved models, the system can achieve superior performance in terms of detection accuracy.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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