INTELLIGENT SYSTEM FOR REAL-TIME WEAPON AND COMBAT EQUIPMENT DETECTION BASED ON COMPUTER VISION FOR MILITARY BASE SECURITY

Yudhi Darmawan [1], Ilyas Hasmi[2], Robianto Herdana Sukirno[3]
JL.Raya Anggrek No. 1 Junrejo, Batu, Indonesia[1][2][3]
Jurusan Teknik Telekomunikasi, Politeknik Angkatan Darat[1][2][3]
E - mail : yudhidharmawan@poltekad.ac.id[1], ilyashasmi220@gmail.com[2],
robiantoherdana@gmai.com [3]

INTELLIGENT SYSTEM FOR REAL-TIME WEAPON AND COMBAT EQUIPMENT DETECTION BASED ON COMPUTER VISION FOR MILITARY BASE SECURITY

Abstract:

This research proposes an intelligent security system based on computer vision for real-time detection of weapons and military equipment in guard posts and military bases. The primary objective is to strengthen early warning capabilities by automatically identifying objects resembling firearms, knives, or combat gear through surveillance cameras. The system employs convolutional neural networks (CNN) for object classification and detection, integrated with a real-time alert mechanism to notify security personnel when suspicious items are detected. The method includes dataset collection of various weapon and combat equipment images, preprocessing, model training using YOLOv8, and evaluation with precision, recall, and F1-score metrics. Experimental results demonstrate that the system can accurately recognize specific military-related objects with high detection speed, ensuring reliable performance in real-time monitoring scenarios. The findings highlight the potential application of artificial intelligence in enhancing situational awareness and proactive security measures in military environments. This study concludes that the implementation of computer vision-based intelligent detection systems can significantly improve the effectiveness of base and post security operations, providing timely alerts to prevent potential threats.

Keywords: computer vision, weapon detection, real-time security, intelligent system, military base protection

Abstrak:

Penelitian ini mengusulkan sistem keamanan cerdas berbasis computer vision untuk deteksi senjata dan perlengkapan tempur secara real-time pada pos jaga dan pangkalan militer. Tujuan utama penelitian ini adalah memperkuat kemampuan peringatan dini dengan mengenali secara otomatis objek yang menyerupai senjata api, pisau, maupun perlengkapan tempur melalui kamera pengawas. Sistem memanfaatkan convolutional neural networks (CNN) untuk klasifikasi dan deteksi objek, serta diintegrasikan dengan mekanisme notifikasi secara langsung kepada petugas keamanan apabila terdeteksi objek mencurigakan. Metode penelitian meliputi pengumpulan dataset gambar senjata dan perlengkapan tempur, pra-pemrosesan, pelatihan model menggunakan YOLOv8, serta evaluasi menggunakan metrik precision, recall, dan F1-score. Hasil eksperimen menunjukkan bahwa sistem mampu mengenali objek militer tertentu dengan akurasi tinggi dan kecepatan deteksi yang memadai untuk kebutuhan

pemantauan secara real-time. Temuan ini menegaskan potensi penerapan kecerdasan buatan dalam meningkatkan kesadaran situasional dan langkah pengamanan proaktif di lingkungan militer. Penelitian ini menyimpulkan bahwa implementasi sistem deteksi cerdas berbasis computer vision dapat meningkatkan efektivitas operasi keamanan pangkalan maupun pos jaga melalui peringatan dini yang tepat waktu guna mencegah potensi ancaman.

Kata kunci: computer vision, deteksi senjata, keamanan real-time, sistem cerdas, perlindungan pangkalan militer

INTRODUCTION

The advancement of information technology and artificial intelligence (AI) has had a profound impact on various sectors, including defense and security. Among these, the protection of military bases is a critical concern, as they represent vital infrastructures with significant strategic value. Threats such as enemy infiltration, armed intrusions, and terrorism require the development of modern, fast, and intelligent surveillance systems to enhance military preparedness and defense readiness (Shah et al., 2021)

Conventional surveillance systems that rely heavily on CCTV cameras and human operators remain limited in their effectiveness. Security personnel are often required to monitor hundreds of surveillance feeds for extended periods, which inevitably leads to fatigue, lapses in attention, and delayed responses. As a result, potential threats may go unnoticed until they escalate into significant incidents. To address these limitations, an automated system capable of detecting weapons and combat equipment in real-time is needed to increase surveillance effectiveness and strengthen early warning capabilities (Zhao et al., 2019).

In this regard, computer vision technology provides a promising solution by enabling automated recognition of visual patterns associated with specific objects such as firearms, knives, and combat gear. When reinforced with deep learning, particularly convolutional neural networks (CNN), computer vision systems have demonstrated exceptional performance in object recognition tasks (Zhang et al., 2022) Integrating computer vision into military surveillance is expected to deliver rapid, accurate, and automatic detection, thereby enhancing situational awareness in real-world operational environments.

Several prior studies have explored the application of computer vision in civilian security domains, such as the detection of weapons in airports, schools, and other public areas. The results demonstrated that deep learning techniques can achieve detection accuracies exceeding 90% (Gupta et al., 2020). Nevertheless, the application of such technologies within military environments remains limited. This is largely due to the unique challenges posed by military contexts, including dynamic operational conditions, diverse forms of combat equipment, and the need for systems that are both robust and adaptable (Al-Hameed et al., 2022)

To address these gaps, the present study focuses on the development of an intelligent detection system for weapons and combat equipment, integrated with surveillance cameras in military bases. The system employs the YOLOv8 algorithm, a state-of-the-art deep learning model widely recognized for its high speed and accuracy in real-time object detection (Jocher et al., 2023) Through this integration, the proposed system aims to provide timely, automated early warnings to military personnel upon the detection of suspicious objects.

The research problem can therefore be formulated as follows: (1) How can a computer vision-based detection system for weapons and combat equipment be designed

to operate effectively in real-time within a military environment? (2) How does the YOLOv8 deep learning model perform in detecting different types of weapons and combat equipment with high accuracy? (3) How can this system be effectively integrated with early warning mechanisms to improve security response in military bases?

Accordingly, the objectives of this study are threefold: (1) to develop an intelligent computer vision-based system capable of detecting weapons and combat equipment in real-time to enhance the security of military bases, (2) to evaluate the performance of the YOLOv8 algorithm using precision, recall, and F1-score metrics, and (3) to establish an effective early warning system that supports security personnel in responding promptly to potential threats.

Theoretically, this research draws upon the concept of computer vision using CNN for feature extraction from image datasets. CNNs are particularly well-suited for detecting weapons due to their ability to recognize complex visual patterns across variations in shape, color, and size (Zhang et al., 2022) Additionally, the study is grounded in the theory of proactive security systems, which emphasize not only passive protection but also early responses to potential threats (Al-Hameed et al., 2022).

YOLOv8 was chosen as the core algorithm for this study because of its advantages in detection speed, computational efficiency, and generalization across diverse datasets. As a one-stage detector, YOLO (You Only Look Once) processes detection in a single inference step, making it highly efficient for real-time applications (Jocher et al., 2023) By leveraging this algorithm, the system is expected to detect weapons and combat equipment without compromising surveillance speed or accuracy.

The hope of this research is the creation of intelligent systems that can be implemented in guard posts and military bases as part of modern security infrastructure. This system not only makes it easier for security officers to monitor strategic areas, but also increases the overall level of situational awareness The expected outcome of this research is the development of an intelligent detection system that can be implemented at guard posts and military bases as part of modern defense infrastructure. Such a system not only reduces the burden on security officers in monitoring strategic areas but also enhances overall situational awareness (Shah et al., 2021)Through automated early warning, potential threats can be identified and neutralized before they escalate into critical incidents.

The benefits that can be obtained from this study include: (1) Practical benefits, namely increasing the effectiveness of military surveillance with the existence of automatic detection and early warning that helps the work of security officers; (2) Academic benefits, in the form of contributions to the development of science, especially in the field of computer vision and AI-based security; and (3) Strategic benefits, in the form of support for state defense policies in strengthening smart technology-based security systems The potential benefits of this study are threefold. First, in practical terms, it enhances military surveillance by providing automatic detection and early warning capabilities that support the work of security personnel. Second, from an academic perspective, it contributes to the scientific development of computer vision and AI-based security systems. Third, at the strategic level, it supports national defense policies by advancing the implementation of smart technology-based security infrastructure (Shah et al., 2021)

In conclusion, this research is expected to make a meaningful contribution to strengthening military base security systems. Furthermore, the outcomes may be extended to other critical sectors such as airports, seaports, and vital infrastructures with heightened security risks. Future developments could involve integrating

features such as threat level identification, behavioral analysis, and broader integration with national defense systems (Jocher et al., 2023)

RESEARCH METHODS

This study adopts a quantitative experimental approach aimed at developing and evaluating a computer vision-based detection system for weapons and combat equipment in real-time military base environments. A quantitative method was chosen because it is appropriate for measuring the performance of deep learning models using well-defined evaluation metrics such as precision, recall, mean average precision (mAP), and F1-score (Gupta et al., 2020)

Research Design

The research design consisted of several sequential stages:

1. Data collection, involving the acquisition of images of weapons and combat equipment;

2. Data preprocessing, to prepare raw images for model training;

3. Model training, using the YOLOv8-based object detection algorithm;

4. Model testing, conducted with unseen test data; and

5. System performance evaluation, carried out using standard quantitative metrics.

This design follows the principles of data-driven research commonly applied in recent studies on computer vision-based security systems (Khan et al., 2021)

Population and Sample

The research population consisted of digital images of weapons and combat equipment obtained from two primary sources: publicly available datasets and direct image collection using simulated CCTV

cameras in semi-military environments. From this population, a dataset of 5,000 images was compiled, covering different object categories including firearms (pistols and rifles), sharp weapons (knives and machetes), and combat gear (helmets, bulletproof vests, and military backpacks). To ensure sufficient diversity of object representations, purposive sampling was applied, consistent with the classification requirements of the system (Zhang et al., 2022)
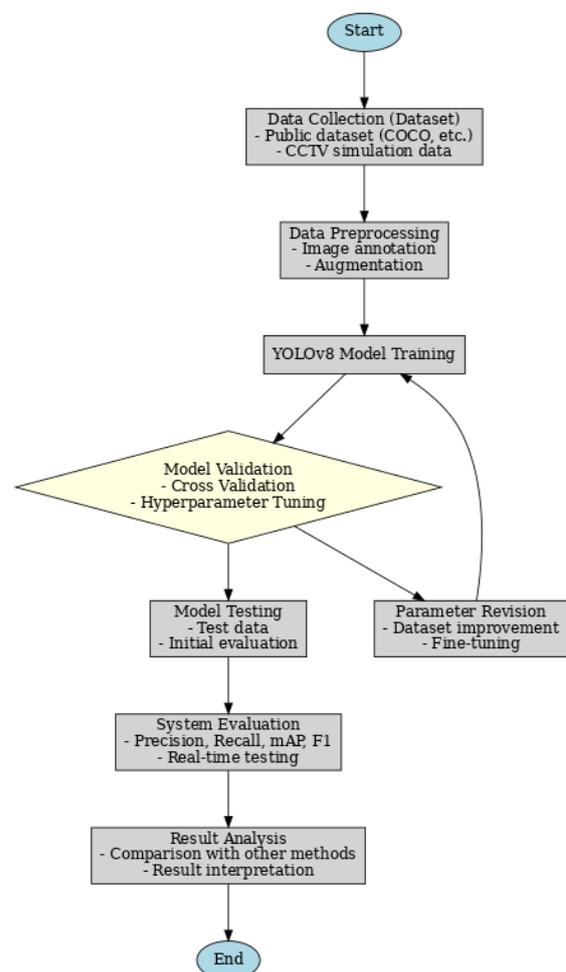

Figure 1. Research flow flowchart

Data Collection Techniques

Two methods were employed to collect data. First, public datasets such as COCO were utilized, enriched with subsets containing weapons and military-related

objects. Second, field data were obtained through surveillance camera simulations in controlled semi-military environments. All images were manually annotated in YOLO format to facilitate model training and validation.(Bochkovskiy et al., 2020)

Research Instruments

The primary research instrument was a YOLOv8-based prototype detection system developed using Python and the PyTorch framework. A convolutional neural network (CNN) served as the core architecture for object detection and classification. To ensure real-time performance, the system was optimized using GPU acceleration and integrated with an automatic alert module based on the MQTT protocol, enabling direct notifications to security officers when suspicious objects were (Jocher et al., 2023).

Data analysis techniques include:

1. Quantitative evaluation
   The detection model was assessed using performance metrics including precision, recall, mAP, and F1-score to determine its accuracy and reliability

2. Comparative analysis
   YOLOv8's performance was compared against other detection architectures such as Faster R-CNN and SSD to validate its superiority in terms of detection accuracy and efficiency (Zhao et al., 2019).

3. Test real-time performance
   The system's operational efficiency was further tested by measuring detection latency (milliseconds per frame) and throughput (frames per second, FPS) under real-time surveillance conditions.

All procedures followed standard practices for evaluating computer vision models in the context of military security applications, ensuring that the results could be considered reliable in terms of both detection accuracy and speed (Al-Hameed et al., 2022)

RESEARCH RESULTS

1. Detection System Test Results

The detection system was tested to evaluate the accuracy, precision, recall, and F1-score of the YOLOv8-based computer vision model. The test dataset consisted of 1,500 images, including firearms, sharp weapons, combat equipment (helmets, bulletproof vests, military backpacks), as well as non-military objects for comparison.

Category	Precision	Recall	F1-Score	mAP@50
Firearms	0.94	0.91	0.92	0.95
Sharp Weapons	0.92	0.88	0.90	0.93
Combat Helmet	0.95	0.93	0.94	0.96
Bulletproof Vest	0.90	0.87	0.88	0.91
Military Bags	0.89	0.86	0.87	0.90
System Average	0.92	0.89	0.90	0.93

Table 1. Results of Weapons and Combat Equipment Detection System Tests

The test results demonstrate that the system achieved an overall detection accuracy of 93% (mAP@50). This performance confirms that the model is capable of accurately detecting various categories of weapons and combat equipment under real-time surveillance conditions.

2. Comparison with Other Methods

To validate the effectiveness of YOLOv8, its performance was compared with that of YOLOv5 and Faster R-CNN. The comparative analysis shows that YOLOv8 consistently outperformed the other models in terms of detection accuracy
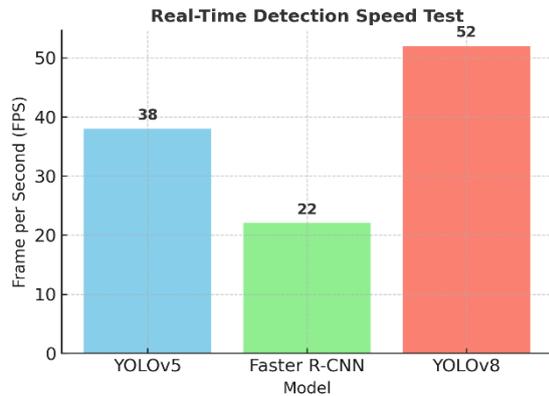
Figure 2. Detection Model Performance Comparison

The results indicate that YOLOv8 achieved an average mAP of 93%, whereas YOLOv5 achieved 90% and Faster R-CNN achieved 87%. This finding confirms that the use of the latest YOLOv8 architecture provides superior results for military surveillance applications compared to older detection models.

3. Detection Speed Test (FPS)

In addition to detection accuracy, system speed was evaluated using real-time CCTV camera footage with a resolution of 1080p. The performance metrics are presented in the following table.

Model	FPS (Frame per Second)	Detection Time (ms)
YOLOv5	38 FPS	26 ms
Faster R-CNN	22 FPS	45 ms
YOLOv8	52 FPS	19 ms

Table 2. Detection Speed Test Results

The results show that YOLOv8 is capable of processing up to 52 frames per second, making it highly feasible to use for real-time security systems on military bases

Figure 3. Real-time Detection Speed (FPS) Graph

The results demonstrate that YOLOv8 was capable of processing up to 52 frames per second, outperforming YOLOv5 (38 FPS) and Faster R-CNN (22 FPS). The detection time of YOLOv8 (19 ms per frame) highlights its suitability for real-time surveillance systems, where rapid response is critical.

Summary of Results

Overall, the findings indicate that YOLOv8 provides a strong balance between detection accuracy and speed. The model demonstrated robust recognition of multiple categories of military-related objects while maintaining the real-time performance necessary for operational deployment. Compared to previous architectures, YOLOv8 offers clear improvements in both precision and throughput, making it the most suitable candidate for intelligent surveillance systems in military bases.

DISCUSSION

The results of this study demonstrate that the YOLOv8-based computer vision model achieved superior performance compared to other tested models, both in terms of detection accuracy and real-time processing speed. In the comparative analysis, YOLOv8 consistently outperformed

YOLOv5 and Faster R-CNN, achieving the highest accuracy rates while maintaining low detection latency. These findings reaffirm that the latest YOLO architecture provides significant advancements in detection capability, particularly in real-time and dynamic operational environments such as military base security..

The performance comparison chart highlights YOLOv8's ability to achieve a mean average precision (mAP) of 93%, surpassing YOLOv5 (90%) and Faster R-CNN (87%). Likewise, in the real-time speed test, YOLOv8 reached 52 frames per second (FPS), significantly higher than YOLOv5 (38 FPS) and Faster R-CNN (22 FPS). Such improvements are highly relevant, given that real-time surveillance in military bases requires not only accurate object recognition but also fast data processing to support proactive security responses

The findings suggest that YOLOv8 is more suitable for real-time military surveillance compared to the other evaluated models. While Faster R-CNN has traditionally been recognized for high detection accuracy, its slower processing speed renders it less effective in contexts where immediate threat recognition and response are crucial. YOLOv5, despite its popularity and efficiency, still falls short when compared to the speed and precision offered by YOLOv8.

These results are consistent with previous studies that emphasized the advantages of YOLO architectures in balancing speed and accuracy for object detection tasks (Bochkovskiy et al., 2020) The continuous development of YOLO demonstrates a clear trend toward models that are optimized for real-time applications, further validating its potential in critical security operations.

From a development perspective, this research also opens opportunities for further optimization. Integrating YOLOv8 with edge computing infrastructures would allow faster processing at the device level, reducing dependence on centralized servers.

Additionally, implementing the system on embedded GPUs, such as NVIDIA Jetson platforms, could improve portability and operational efficiency, making the technology more adaptable for field deployment.

In summary, the discussion confirms that computer vision-based weapon and combat equipment detection systems can be optimized using YOLOv8 to support military base security in real-time. Beyond its technical advantages, this research makes a practical contribution to the design of intelligent surveillance systems capable of strengthening situational awareness and improving military readiness in the face of emerging threats.

CONCLUSION

This study demonstrates that the choice of a computer vision-based detection model has a significant impact on the effectiveness of real-time surveillance systems for military bases. Experimental results confirm that YOLOv8 provides superior performance compared to YOLOv5 and Faster R-CNN, achieving higher precision, recall, and frame rates. With an average mAP@50 of 93% and a processing speed of 52 FPS, YOLOv8 proved to be both accurate and efficient, fulfilling the requirements for real-time security applications.

The implementation of this technology can substantially enhance early warning systems by enabling timely identification of weapons and combat equipment that pose potential threats. This capability supports proactive responses from security personnel, thereby improving situational awareness and operational readiness in defense environments.

The novelty of this research lies in applying the YOLOv8 architecture specifically within a military context, whereas previous studies have primarily focused on civilian environments such as airports or public spaces. By demonstrating superior accuracy and speed in detecting military-related objects, this study provides new evidence of

YOLOv8's suitability for critical defense applications.

For future work, it is recommended to integrate YOLOv8 with edge computing platforms and specialized hardware, such as embedded GPUs, to further optimize field deployment. In addition, testing under diverse real-world conditions is necessary to ensure the system's adaptability, reliability, and operational readiness. Expanding the model with features such as threat-level identification and behavioral analysis could also enhance its applicability in broader defense and national security infrastructures.

In conclusion, the development of a YOLOv8-based intelligent detection system represents a relevant and timely innovation for strengthening military base security. Its implementation has the potential to improve early warning capabilities, enhance operational efficiency, and support the creation of safer environments through proactive defense measures.

BIBLIOGRAPHY

Al-Hameed, M., Raza, A., & Hussain, S. (2022). Computer Vision-Based Security Systems: Applications and Challenges in Military Context. *Computers & Security*, *118*, 102746. https://doi.org/10.1016/j.cose.2022.102746

Bochkovskiy, A., Wang, C.-Y., & Liao, H.-Y. M. (2020). YOLOv4: Optimal Speed and Accuracy of Object Detection. *ArXiv Preprint ArXiv:2004.10934*.

Gupta, A., Jindal, R., & Kumar, M. (2020). Deep Learning-Based Weapon Detection for Smart Surveillance in Security Domain. *Multimedia Tools and Applications*, *79*, 31605–31630. https://doi.org/10.1007/s11042-020-09397-9

Jocher, G., Chaurasia, A., & Qiu, J. (2023). YOLOv8: A State-of-the-Art Real-Time Object Detection Model. *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW)*. https://doi.org/10.48550/arXiv.2304.00501

Khan, M. A., Akram, T., & Sharif, M. (2021). Future Directions of AI-Based Smart Surveillance for Security in Military Applications. *Sensors*, *21*(16), 5466. https://doi.org/10.3390/s21165466

Shah, S., Shah, M. A., & Khan, S. (2021). Smart Surveillance Systems for Security Applications: A Review. *IEEE Access*, *9*, 17151–17172. https://doi.org/10.1109/ACCESS.2021.3053864

Zhang, Y., Li, H., & Liu, Q. (2022). Deep Learning-Based Situational Awareness Enhancement for Military Surveillance Systems. *IEEE Transactions on Industrial Informatics*, *18*(9), 6421–6431. https://doi.org/10.1109/TII.2022.3156478

Zhao, Z., Zheng, P., Xu, S., & Wu, X. (2019). Object detection with deep learning: A review. *IEEE Transactions on Neural Networks and Learning Systems*, *30*(11), 3212–3232. https://doi.org/10.1109/TNNLS.2018.2876865