Designing a Prototype Intrusion Detection System Based on YOLO V5 at Surabaya Aviation Polytechnic

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ABSTRACT

Surabaya Aviation Polytechnic requires a more efficient and responsive surveillance system to maintain campus security, particularly in perimeter areas prone to unauthorized access. Currently, the surveillance system relies on conventional CCTV cameras that require manual monitoring by security personnel, resulting in limitations in detecting incidents in real-time. This research aims to develop a prototype of an automatic intrusion detection system based on cameras and the YOLOv5 object detection algorithm. The system is designed to directly detect the presence of humans and non-human objects through video footage from the cameras. Detected objects are marked using bounding boxes, and the system distinguishes whether the object is human or not. If the detected object is human, the system activates a buzzer via an ESP32 microcontroller as a warning notification. This research adopts a prototype approach, including stages of needs identification, system design, hardware and software development, and functional system testing. Testing was conducted using a dataset containing 500 human images and 500 non-human images to train the detection model. The test results show that the system can automatically detect intrusions, but it still has limitations in terms of accuracy, detection speed, and notification effectiveness. Therefore, the system still requires further development.

Keywords: *YOLO V5, Python, intrusion detection, prototype approach, ESP32, campus perimeter security*

A. INTRODUCTION

Surabaya Aviation Polytechnic is a higher education institution that upholds discipline and safety in the learning environment. However, violations such as cadets entering or exiting through unofficial routes, especially in the poorly supervised area behind the dormitory, are still found. The current CCTV system is passive, only recording without providing immediate response [1]. To address these limitations, an intelligent surveillance system is needed that can automatically detect violations and provide real-time responses.

YOLO V5 (You Only Look Once version 5) is a deep learning-based object detection algorithm that can recognize objects quickly and accurately. This technology has been applied in various sectors, such as agriculture [2] and traffic [3], but has not yet been widely utilized in campus environments. With its ability to classify objects based on shape, color, and patterns, along with an alarm in the form of a buzzer, this system can serve as an effective solution for monitoring campus perimeter areas.

Through this final project, the author designed a prototype monitoring system using YOLO V5 to detect human and non-human objects in the area behind the dormitory. This system is integrated with a local web application that can be used by security officers in real time. Through this final project, the author developed a prototype of an intelligent surveillance system titled "DESIGN AND CONSTRUCTION OF A YOLO V5-BASED INTRUSION DETECTION SYSTEM PROTOTYPE AT THE SURABAYA AVIATION POLYTECHNIC."

1. How to design and build a prototype intrusion detection system for the perimeter area of the Surabaya Aviation Polytechnic dormitory by utilizing the YOLO V5 algorithm in real-time to overcome the limitations of manual surveillance and conventional CCTV?
2. How does the YOLO V5 method work to detect violations committed in the rear perimeter area of the dormitory?

B. THEORY

1. Prototype

A prototype is an initial model designed to represent a product or system before it is mass-produced. The purpose of a prototype is to show the physical form, function, and size of a product in real terms, thereby facilitating the testing and adjustment process [4].

2. *Perimeter Intrusion Detection System (PIDS)*

The Perimeter Intrusion Detection System (PIDS) is one type of system used to detect intruders. According to [5], PIDS is a security solution designed to monitor the outer perimeter of an area or facility. This system can used to detect unwanted movement or intrusion within the perimeter of the Inspection Road, enabling a rapid response to address the situation.

2. *You Only Look Once (YOLO)*

You Only Look Once (YOLO) is an algorithm developed based on the previous algorithm, namely CNN (Convolutional Neural Network). YOLO is specifically designed for real-time object detection, and the system is capable of processing images at a speed of 45 Frames Per Second (FPS) [6]. The object detection process is carried out through reclassification or localization. This model is applied to images in various locations and scales. The area with the highest score in the image will be considered as a successfully detected object.

3. *Computer vision*

Computer vision is a branch of computer science that focuses on developing systems that can process, analyze, and understand visual data (such as images or videos) in a way that resembles how humans see [7]. This technology enables systems to identify important information in images, videos, and other visual inputs, and make decisions or provide recommendations based on the data obtained. The essence of computer vision is teaching computers to process images at the pixel level and understand their meaning.

4. *Logitech C270 Webcam*

The Logitech C270 Webcam is a device designed to meet the needs of HD video calls. With a maximum resolution of 1280 x 720 pixels and a frame rate of up to 30 fps, this webcam is capable of producing adequate image quality. It is equipped with an internal microphone, so users can make video calls directly without the need for an additional external microphone[8].

5. *Piezoelectric buzzer*

A piezoelectric buzzer is a transducer that converts electrical signals into sound or vibration. This type of buzzer is commonly used in alarm clocks, doorbells, and hazard warning devices because it is generally inexpensive, easy to integrate, and requires only a simple electrical signal without complex circuits[9].

6. *ESP32*

ESP32 is a microcontroller that works by integrating a dual-core processor, Wi-Fi module, and Bluetooth in a single chip, enabling efficient data processing and wireless communication. The ESP32 microcontroller acts as the brain or control center for managing input and output devices[10]. The ESP32 works by reading input from sensors or external devices, then processing the data using a program that has been loaded into the microcontroller's memory. Once processed, the data can be sent to other devices via a Wi-Fi or Bluetooth connection, or used to control output devices such as buzzers, relays, or LCD screens.

7. *Python*

Python is a flexible and versatile programming language with an interpretive system that emphasizes code readability in its design. The language is known for combining power, flexibility, and easy-to-understand syntax, and is supported by an extensive and comprehensive standard library. Additionally, Python has a large and active community, making it easier for users to share knowledge and solve problems through discussions with fellow users [11].

8. *PyTorch*

PyTorch is a library in the Python programming language designed for Deep Learning computations [12]. With a focus on flexibility, PyTorch simplifies the creation of Deep Learning models using Python syntax, making it popular among academic researchers. Since its launch, the library has grown rapidly and has become one of the main tool widely used in Deep Learning processing.

9. Open Computer Vision (OpenCV)

Open Computer Vision (OpenCV) is a digital image processing module that is useful for creating, modifying, and processing images, so that it can be maximized in various programming applications, especially in the object detection process[13].

10. *Google Colaboratory (Colab)*

Google Colaboratory (Colab) is a free cloud service provided by Google, offering a Jupyter Notebook interface that is very useful for development and training in the field of machine learning. One of the main advantages of Colab is free access to GPUs and TPUs, which facilitates the training process of neural network models that require high computing power, such as YOLO V5 [14].

C. METHOD

This study uses a *Research and Development* (R&D) approach with a prototype development model, which aims to design and build a YOLO V5-based intrusion detection monitoring system. This method was chosen because it is suitable for developing technology products in a structured and gradual manner. However, in the scope of this study, the development process only covers the stages of needs identification, initial design, prototype creation, and system testing.

1. Initial Needs Assessment

The author conducted interviews with security personnel at the Surabaya Aviation Polytechnic campus to understand the issues and surveillance needs in the perimeter fence areaof the Surabaya Aviation Polytechnic dormitory.

2. Initial Design Plan

The author designed what needed to be prepared, including system workflow design and determination of the hardware to be used, namely webcams, ESP32 microcontrollers, buzzers as alarms, and laptops as system hosts.

3. Prototype Development

Prototype development, where the system is built based on the initial design to demonstrate how object detection (human and non-human) is performed automatically.

4. System Testing

The final stage, where the newly built system is tested to identify its weaknesses.

After that, the application is evaluated and improved until it is perfected.

D. RESULTS AND DISCUSSION

1. Identification of Initial Needs

In the context of developing this intrusion detection system, the primary users are campus security officers, such as security guards responsible for protecting the perimeter area from potential external threats and disciplinary violations by cadets. Based on interviews with security officers, it was found that most officers do not have a technical background in information technology or programming. Therefore, the system is designed to be easy to use with a simple interface.

The main user requirements include a real-time visual display that can clearly show human and non-human objects, complete with bounding boxes and classification labels. In addition, the system must be able to provide automatic warnings via a buzzer when a detection occurs, without requiring manual intervention. Users also need a system that can automatically store visual evidence in the form of images for documentation and follow-up purposes.

2. Initial Design Plan

The initial design of this system was developed with reference to user needs and the main functions to be achieved, namely automatic intrusion detection and monitoring in the campus perimeter area. The system is designed to be implemented in prototype form using integrated hardware and software.

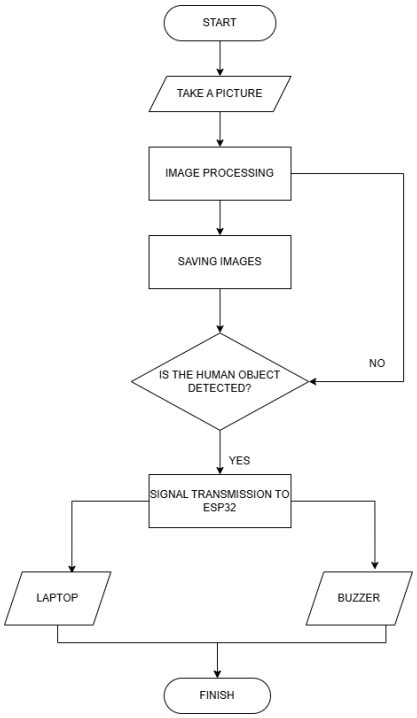

Figure 1. Flowchart of How the System Works

Intrusion detection at the perimeter fence

Based on the flowchart in Figure 2, the intrusion detection system begins with a continuous image capture process. Once the image has been successfully captured, the system will proceed to the image processing stage using object detection methods to identify the presence of humans. The processed images will then be automatically saved to the documentation folder. Next, the system will check the image, specifically at the stage “Is a human object detected?”. If no human object is detected, the system will return to the image capture stage and repeat the process from the beginning. However, if a human object is detected, the system will send a signal to the ESP32 to activate the warning. This signal is transmitted to two outputs: the laptop as a visual monitoring display, and the buzzer as an audio warning device.

1. Prototype Development

The development of this intrusion detection system prototype involves the assembly of all components, both hardware and software, to

ensure that the system functions as designed. The system is designed to automatically detect the presence of human objects crossing over the perimeter fence, with the camera focused specifically on that area.

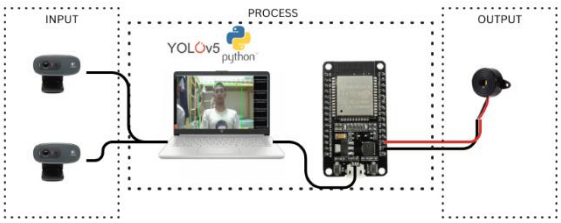

Figure 2 Overall Diagram of the Device

The detection process utilizes a camera connected to a computer, where the recorded images are processed in real-time using the YOLO V5 detection algorithm. If a human object is detected, the system automatically saves the image as documentation and sends a signal to the ESP32 microcontroller to activate the buzzer as an audible warning, and this entire process occurs automatically.

1. System Testing

System testing was conducted to ensure that the developed prototype functioned according to the specified specifications. Testing was conducted in a simple scenario that simulated real conditions on campus, specifically in the area behind the dormitory, where cameras were installed on the perimeter fence to monitor object movement.

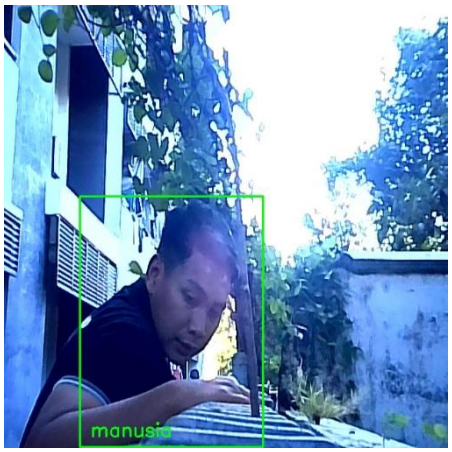

Figure 3 System Display When Detecting

The system was tested to detect the presence of human and non-human objects passing through the surveillance area. Several key aspects were evaluated, including the system's accuracy in recognizing objects, response speed to detection, and the effectiveness of buzzer alerts. The primary objective of this testing is to evaluate whether the detection system can be reliably operated by campus security personnel in the context of real-time perimeter area monitoring.

The black box testing table for on-site testing is provided in the following table.

Table 1 Black Box Testing

Scenario	Detection Occurred?	Active Alarm	clarification correct?
People climbing the perimeter fence	YES	YES	AS PER
Birds/objects within the perimeter area	YES	NO	ENOUGH
Empty area	YES	YES	NOT SUITABLE

E. CONCLUSION

Based on the discussion of the research results entitled “Design of a YOLO V5-Based Intrusion Detection System Prototype in the Back Perimeter Fence Area of the Surabaya Aviation Polytechnic Dormitory,” the author may have reached the following conclusions:

1. The design of the prototype monitoring system for detecting violations in the perimeter area was carried out through the following stages: identifying user needs, system design, hardware implementation, and integration with the YOLOv5-based detection model. This system is capable of automatically and in real-time detecting the presence of both human and non-human

objects. The prototype provides output in the form of bounding boxes and object labels on the video display and has the potential for further development with a warning or alarm system as a response to violations.

2. The YOLOv5 system operates in real-time to detect and recognize objects using a model trained with relevant datasets. This system is capable of identifying the presence and position of objects from camera captures, then comparing them with predetermined parameters. When a deviation is detected, the system automatically records and issues a warning as an indication of a violation.

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