

Darklytic: Real-Time Object Detection Under Night Spectrum

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Abstract: Darklytic is developed to address the challenges of identifying objects in night-time environments. Traditional vision-based detection systems often fail under poor illumination due to noise, low contrast, and loss of visual details. To overcome these limitations, the proposed system integrates infrared-assisted imaging with an optimized deep learning-based object detection model. By enhancing grayscale image features and applying efficient preprocessing techniques, Darklytic improves object visibility and detection accuracy even in near-dark conditions.

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I. INTRODUCTION

Night vision object detection systems are advanced surveillance and monitoring solutions designed to identify objects, humans, or activities in low-light or complete darkness environments. These systems combine imaging hardware, such as infrared (IR) cameras or IR-assisted modules, with intelligent software algorithms to enable visibility beyond the limitations of human vision. traditional cameras rely on visible light, illumination or thermal sensing to capture clear images even in ambient light. in applications such as security surveillance, wildlife monitoring, border control, smart homes, and industrial safety.

In recent years, the integration of the performance of night vision object detection. Low-cost microcontrollers like the ESP32-CAM can capture and stream real-time video over Wi-Fi, while external processing units such as laptops or edge devices analyze the video feed OpenCV. Deep learning models, especially YOLO(You Only Look Once), have become popular for real-time object detection due to their high accuracy and fast processing speed. These models can efficiently detect such as vehicles, even under challenging night-time conditions.

Infrared illumination night vision systems by providing non-visible light that enhances image clarity without alerting or disturbing the surroundings. IR LEDs illuminate the scene, and the camera sensor captures the reflected infrared light to form a visible image. When combined with AI-based detection algorithms, The system goes beyond simple video streaming by analyzing the live feed in real time, detecting relevant objects, and visually marking them with clearly defined

bounding boxes for easy identification. increases reliability in continuous monitoring scenarios.

Overall, night vision object detection systems represent a powerful and cost-effective solution for real-time surveillance in low-light environments. By leveraging embedded hardware, wireless communication, and AI-driven improved accuracy, scalability, and accessibility. Their compact design and energy-efficient operation further smart applications where continuous, intelligent monitoring is required.

➤ Importance of Surveillance in Low-Light Conditions

Surveillance night-time conditions ensuring safety and security, as a large percentage of unauthorized activities, crimes, and intrusions occur after dark. Poor visibility significantly reduces the effectiveness of traditional cameras, making it difficult to identify people, objects, or suspicious movements. Low-light surveillance systems equipped help overcome these challenges by visuals is especially important for protecting sensitive areas such as residential premises, industrial zones, parking areas, borders, and public infrastructure where continuous monitoring is essential.

With advancements in infrared (IR) imaging and intelligent object detection, low-light surveillance has become more accurate and reliable. Integrating night vision cameras with AI-based object detection systems enables real-time identification of humans, vehicles, and unusual activities without relying on visible light. awareness, also reduces false alarms and human monitoring effort. As a result, low-light surveillance systems contribute significantly to crime prevention, emergency response, and overall public safety,

making them an indispensable component of modern security solutions.

➤ *Need for Real-Time Object and Human Detection*

Real-time object and human detection has become essential in modern surveillance and security systems and situational awareness. Traditional monitoring systems require continuous human supervision, which is inefficient and prone to errors by automatically identifying humans and objects as they appear, real-time detection systems significantly reduce reaction time and help prevent security breaches, accidents, or unauthorized access. This capability is especially valuable in sensitive areas such as campuses, industrial sites, borders, and residential zones.

Moreover, real-time detection enhances safety and decision-making in low-light and night-time environments where visibility is limited. Integrating intelligent detection algorithms allows systems to consistent monitoring. When combined with night-vision technology, real-time object and human detection enables reliable performance even in a critical component of smart surveillance, automation, and security applications.

This paper describes the development and implementation of Darklytic designed to operate effectively in low-light and night-time environments. The system focuses on improving object visibility and detection accuracy when conventional camera-based methods struggle due to poor illumination. By combining infrared-assisted image capture with deep learning-based object detection techniques, Darklytic enables reliable recognition of objects even in near-dark conditions.

II. LITERATURE SURVEY

Early object detection methods were primarily built edge detection, background modeling, optical flow, extraction. Approaches like Haar Cascade classifiers, Histogram of Oriented Gradients (HOG), and Scale-Invariant Feature Transform (SIFT) were widely applied, particularly in controlled environments with consistent lighting. The Haar Cascade algorithm introduced by Viola and Jones marked an important step in real-time face detection due to its computational efficiency.

➤ *Deep Learning-Based Object Detection Models*

The introduction revolutionized object detection methods data. Popular object detection architectures include R-CNN, Fast R-CNN, Faster R-CNN, SSD (Single Shot Detector), and YOLO. YOLO(You Only Look Once), proposed by Redmon et al., is a single-stage in one forward pass high speed and reasonable accuracy, YOLO has become suitable for real-time applications. Subsequent versions such as YOLOv3, YOLOv4, YOLOv5, and YOLOv8 improved detection accuracy and efficiency. However, most YOLO models are trained on datasets captured under normal lighting conditions. Their performance degrades significantly in night-time scenarios where visual features are unclear. Researchers have attempted to fine-tune YOLO models using low-light

datasets to improve detection performance under poor illumination.

➤ *Night-Time Object Detection Challenges*

Night-time object detection introduces absent in daylight environments. These include:

- Low visibility and poor contrast.
- High sensor noise.
- Blur caused by motion and low shutter speed.
- Limited color information.
- Uneven illumination from artificial light sources.

Due to these factors, conventional RGB cameras struggle to capture sufficient details at night. As result, object detection accuracy drops significantly. Studies shown that night-time detection accuracy can reduced by more than 40% compared to daytime performance when using standard RGB cameras. To Overcome these Challenges, researchers have proposed alternative sensing modalities such as infrared imaging and thermal vision.

➤ *Infrared and Thermal Imaging for Night Vision*

Infrared (IR) imaging has emerged as a powerful solution for night-time object detection. IR cameras capture radiation emitted or reflected by objects, allowing visibility even in complete darkness. Near-Infrared (NIR) cameras combined with IR LED illumination night surveillance systems. identifying humans and animals regardless of lighting conditions. However, thermal sensors are expensive and consume more low-cost embedded applications. object detection performance using IR images Researchers trained CNN models on infrared datasets and reported higher detection accuracy compared to RGB images at night. However, the high cost of IR sensors limits their large-scale deployment. The proposed DARKLYTIC system uses affordable IR LEDs with a standard camera module, providing an economical solution for night-time object detection.

➤ *Conclusion of Literature Survey*

This survey outlines the shift to deep learning-based object detection. While detection performance has improved under normal lighting, night-time scenarios remain difficult to handle. Many existing methods require costly hardware or high computational power. The proposed DARKLYTIC: Real-Time Object Detection under Night Spectrum aims to bridge this gap by combining IR-assisted imaging, lightweight deep learning models, and optimized inference techniques. The system focuses on affordability, real-time performance, and deployment on embedded platforms, making it suitable for practical night-time surveillance and security applications.

III. PROPOSED FRAMEWORK

➤ *Flow Diagram*

- *IR Illumination Activation*

Infrared (IR) LEDs are switched ON to illuminate the environment in low-light or night conditions.

- **Video Capture by esp32-cam**
The OV2640 camera on the ESP32-CAM captures live video frames using IR illumination.
- **Frame Handling by esp32 Microcontroller**
The ESP32 microcontroller processes basic camera control and prepares frames for transmission.

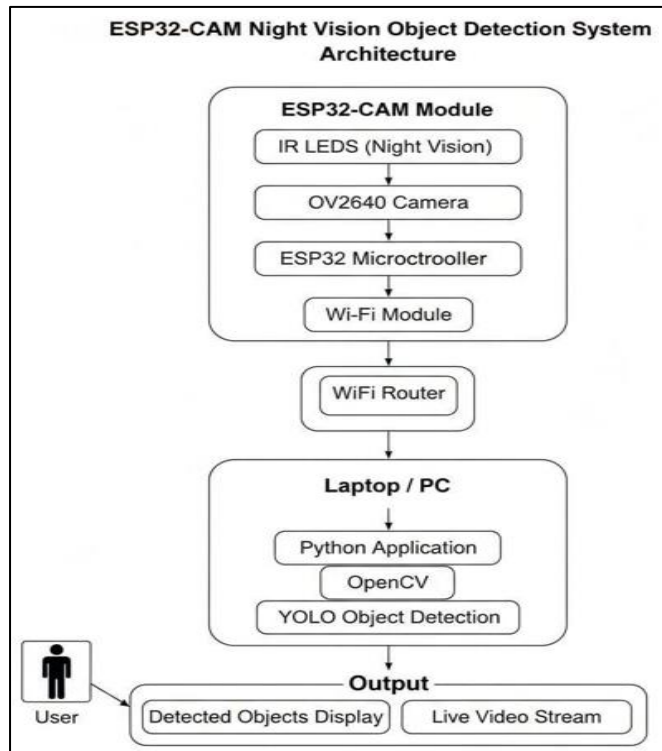


Fig 1 Flow Diagram

- **Wi-fi Video Streaming**
Captured video frames are streamed wirelessly over Wi-Fi through the ESP32's built-in Wi-Fi module.
- **Network Transmission**
The video stream passes through a Wi-Fi router or hotspot to reach the connected laptop/PC.
- **Video Reception on Laptop/PC**
A Python application running on the laptop receives the live video stream.
- **Frame Processing Using OpenCV**
OpenCV processes each frame for resizing, enhancement, and preprocessing suitable for AI analysis.
- **Yolo Object Detection**
The YOLO deep learning model analyzes frames to detect objects and humans in real time.
- **Detection Result Generation**
Bounding boxes, labels, and detected objects.
- **Output Display**
The system displays the detected objects on the user's screen.

- **User Monitoring**
The user observes real-time detection results and monitors activity through the interface.

➤ **System Architecture Block Diagram**

The system architecture of *Darklytic: Real-Time Object Detection Under Night Spectrum* is designed to enable efficient night-time surveillance using an ESP32-CAM module integrated with infrared illumination and an external processing system. The ESP32-CAM acts as the primary image acquisition unit, capturing visual data even in low-light or completely dark environments with the help of IR LEDs. These infrared LEDs illuminate the surroundings without visible light, allowing the camera sensor to collect meaningful image information under night conditions. The captured frames are transmitted wirelessly over a Wi-Fi network to a host computer for further processing.

The received image stream is processed on the host techniques. A pre-trained YOLO- low- light scenarios is employed to identify objects in real time. Before detection, the incoming frames undergo preprocessing steps such as grayscale conversion, histogram equalization, and noise reduction to enhance image clarity and contrast in night conditions. This preprocessing significantly improves detection accuracy when compared to raw low-light images. The detection module then analyzes each frame and identifies objects such as humans, vehicles, or other relevant entities with bounding boxes and confidence scores.

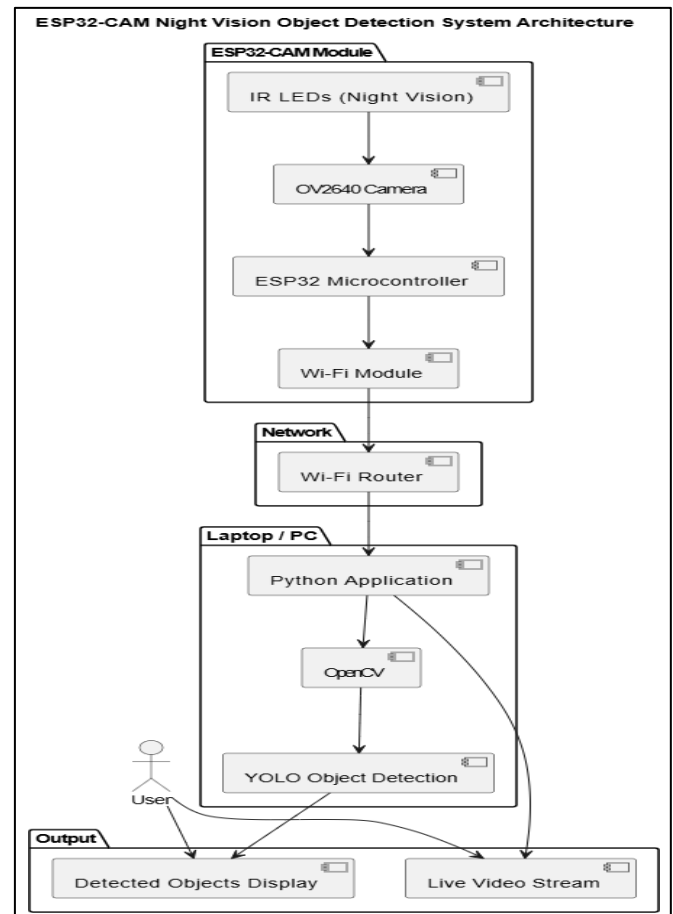


Fig 2 System Architecture

Finally, the output of the object detection process is visualized and monitored through a graphical interface on the host system. Detected objects are highlighted and labeled in real time, enabling effective monitoring and decision-making. The modular design of the system allows scalability, where additional sensors or alert mechanisms can be integrated in future enhancements. Overall, the architecture ensures reliable night-time object detection by combining embedded hardware, infrared illumination, wireless communication, and intelligent deep learning-based analysis.

IV. CONCLUSION

Low-cost night a visual object detection system developed using the ESP32-CAM and computer vision techniques. address the challenge of monitoring and detecting objects in low-light and night-time environments where conventional cameras fail to perform effectively. By combining infrared (IR) illumination with real-time video streaming and YOLO-based object detection, the proposed solution provides an efficient and reliable surveillance mechanism suitable for modern security applications.

The ESP32-CAM module played a vital role in capturing live video under dark conditions with the support of IR LEDs. Its ability to stream video wirelessly over Wi-Fi enabled seamless transmission of real-time footage to a laptop or web browser. The integration of the ESP32-CAM with Python-based processing allowed the computationally intensive object detection tasks to be handled efficiently without overloading the microcontroller. This division of responsibilities improved system stability and performance while keeping the hardware cost minimal.

for object and human detection significantly enhanced the system's accuracy and speed. YOLO's real-time detection capability made it possible to identify humans and objects within each video frame with minimal latency. The system demonstrated reliable detection performance even under low-light conditions, validating infrared illumination combined models. The labels displayed on the processed video provided clear visual feedback, making monitoring easier for the user.

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