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HỆ THỐNG CAMERA AN NINH VỚI TÍNH NĂNG PHÁT HIỆN VÀ CẢNH BÁO BẰNG TIA LASER

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TỪ KHÓA

Internet vạn vật;
Công nghệ Camera;
ESP32-CAM kit;
Lưu trữ đám mây;
Giải pháp an ninh giá rẻ.

TÓM TẮT

Trong những năm gần đây, sự phát triển của công nghệ dựa trên camera đã làm tăng nhu cầu ứng dụng trong nhiều lĩnh vực, đặc biệt là an ninh của mọi người. Ví dụ, camera có thể giúp điều tiết giao thông, sàng lọc bệnh tật, tự động hóa các quy trình công nghiệp và nhận dạng khuôn mặt. Tuy nhiên, hầu hết các ứng dụng này đều yêu cầu các hệ thống phức tạp và đắt tiền mà không phải ai cũng có thể tiếp cận. Trong bài báo này, chúng tôi đề xuất một hệ thống an ninh nhỏ gọn và giá rẻ dựa trên bộ ESP32-CAM, đây là một bộ vi điều khiển có camera tích hợp và Wi-Fi. Hệ thống của chúng tôi có thể phát hiện những kẻ xâm nhập trái phép trong hộ gia đình hoặc bãi đỗ xe bằng cảm biến laser, cảnh báo chúng bằng còi báo động và chụp ảnh chúng để làm bằng chứng. Các hiện tượng bất thường mà hệ thống phát hiện sẽ được gửi đến bộ lưu trữ đám mây qua Wi-Fi. Hệ thống sẽ được ứng dụng trong lĩnh vực an ninh, trong các hộ gia đình hoặc bãi đỗ xe có nhu cầu lắp đặt chi phí thấp. Chúng tôi chứng minh tính khả thi và hiệu quả của hệ thống thông qua các thử nghiệm và đánh giá.

CAMERA-BASED SECURITY SYSTEM FEATURED WITH LASER DETECTION AND WARNING

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ABSTRACT

Recent advancements in camera-based technologies have heightened security demands across various sectors. Cameras now play a pivotal role in traffic management, disease screening, industrial automation, and facial recognition. Nonetheless, many existing solutions are prohibitively expensive and complex, limiting the accessibility for broader applications. This paper introduces an innovative, low-cost, and compact security system utilizing the ESP32-CAM kit, which integrates a microcontroller with a built-in camera and Wi-Fi . Our system is engineered to detect unauthorized individuals in residential settings and parking facilities, employing a laser sensor to trigger alerts via a buzzer and capture photographic evidence for subsequent analysis. Anomalies identified by the system are seamlessly transmitted to cloud storage over Wi-Fi, ensuring real-time monitoring and response. Designed for easy installation and affordability, our system holds significant promise for enhancing security in homes and public areas. Through comprehensive experiments and evaluations, we validate the system's feasibility and effectiveness, demonstrating its potential as a transformative solution in the security landscape.

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1. INTRODUCTION

Imagine a world where security transcends mere visibility, evolving into a proactive and intelligent force that anticipates and addresses potential threats before they materialize. Welcome to the era of camera-based security systems, where cutting-edge technology merges with innovative design to redefine the very boundaries of safety and surveillance. At the forefront of this revolution is a pioneering solution that harnesses the power of laser detection and warning to create an unparalleled layer of protection. Intrusion detection is a critical component of security systems. While various technologies such as infrared, microwave, and ultrasonic sensors have merits, LASER-based systems offer unique advantages that make them a compelling choice for modern security needs. An in-depth analysis was conducted to explore why LASER technology is superior for intrusion detection due to Precision and Accuracy; Long Range Detection; Reduced Susceptibility to Environmental Factors; Cost-Effectiveness Over Time; Enhanced Security Layers; and Integration with Advanced Technologies. Moreover, while traditional intrusion detection solutions such as infrared, microwave, and ultrasonic sensors have served their purposes well, LASER technology presents a range of advantages that position it as a superior choice for modern security needs. Its precision, long-range capabilities, reduced environmental susceptibility, and integration with advanced technologies make it an effective, cost-efficient, and reliable option for safeguarding assets. As security threats continue to evolve, leveraging LASER technology for intrusion detection is not only a choice, but also a strategic imperative for organizations aiming to stay ahead of potential breaches. This groundbreaking system, featuring a sophisticated network of cameras and laser sensors, can detect and track potential intruders with unparalleled accuracy, alerting authorities in real time to respond swiftly and effectively. With its unparalleled fusion of surveillance, detection, and warning capabilities, this camera-based security system is poised to revolutionize how we think about security, making it an indispensable asset for organizations, institutions, and individuals.

In this paper, we will first delve into the intricacies of this remarkable technology, exploring its features, benefits, and applications, as well as exploring the future of security in the age of camera-based surveillance. Next, we will do the literature reviews on such systems designed around the ESP32-CAM microcontroller kit, focusing on their cost-effectiveness while maintaining essential features.

The ESP32-CAM is a microcontroller with a built-in camera and Wi-Fi that can be used for various IoT projects, such as face recognition, video streaming, and image processing [1]. It can also be used for home security by detecting motion or door opening using sensors, capturing images of intruders, and sending them to the owner via the Telegram app or FTP server [2-5]. In addition, the ESP32-CAM can be used for fire, smoke, and gas leak alert systems by connecting it to appropriate sensors and sending notifications to the owner [5]. Moreover, it is a low-cost and compact device that can be easily integrated with other components, such as laser, buzzer, relay, and LED [4, 6].

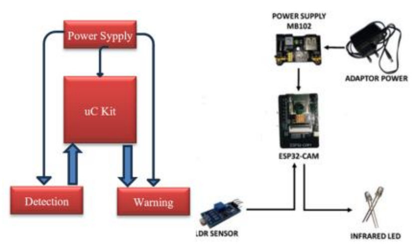
With a scientific, reasonable, and convenient design, the ESP32-CAM has been researched to combine with many types of sensors in many concrete and useful applications in civil security to improve human quality of life with safety being of the utmost concern. A study in [7] discusses the design and implementation of a home security system using the ESP32-CAM module and the Telegram application. It also provides a literature survey on various approaches and techniques proposed by researchers to enhance home security using these technologies. Putra et al [8] propose a room security system design using the ESP32-CAM module with a fuzzy algorithm. The system can detect intruders using a laser sensor and a camera and send notifications to the owner via email and SMS. Another approach in [9] presents a secure image storage and transmission system using the ESP32-CAM module and cloud computing. The system can capture images at regular intervals and store them on a local server, which can be accessed by the receiver. Finally, we present an advanced intelligent smart home control and security system that leverages IoT devices, including the ESP32 camera, PIR motion sensor, ESP8266 development board, and DHT11 temperature and humidity sensor. The system can monitor and control various aspects of the home environment, such as lighting, temperature, humidity, and security.

In this paper, a new design of a Low-Cost ESP32-CAM security system featuring laser detection and warning is proposed. In this design, the ESP32-CAM device is utilized to make the security camera system, which is integrated with a laser light to warn and take pictures of unauthorized intruders. Anomalies detected by the system will be sent to cloud storage via Wi-Fi. The system will be applied in the field of security, in households, or parking lots with low-cost installation needs.

The rest of this paper is organized as follows. The design of the proposed system is described in section 2. In section 3, some experimental results are presented as well. Section 4 concludes the paper with future directions.

2. DESIGN OF THE PROPOSED SYSTEM

The proposed system consists of two parts: hardware and software. Each part is designed separately based on ensuring synchronization, and compatibility with each other. The proposed system block diagram is designed as depicted in Figure 1(a). The corresponding components/devices in each block are shown in Figure 1(b).



(a) (b)

Figure 1. *The proposed Low-Cost ESP32-CAM security system*

2.1 Hardware design

The hardware part consists of a ESP32-CAM kit, photoresistor sensor module, FT232RL board, and a laser light source depicted in Figure 2. The laser emits a light source toward the photoresistor sensor module. This light source will be cut when an intruder breaks into the house. The FT232RL board is used for programming/ coding for the ESP32-CAM kit.

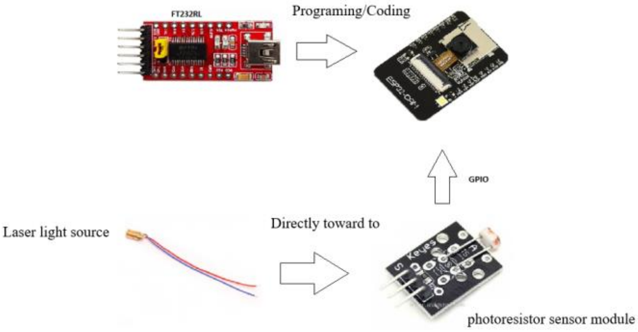


Figure 2. *The proposed system hardware design*

The technical specifications of all hardware components described in Section 5 Appendix indicate the suitability of the hardware design of this proposed system.

2.2 Software design

In this section, we describe in detail the design of a software algorithm. The software is designed to match the hardware mentioned in section 2.1 and is applied to a real physical security system, as shown in Figure 4. The software is summarized by an algorithmic flowchart as depicted in Figure 3.

In the initializing step, the ESP32-CAM tries to connect to the Wi-Fi, and if successful, it will give the IP address and access to view the stream from the kit. The laser will shine on the optical, and the signal output of the photoresistor is HIGH as well. When someone or an object is moved over a laser light source and cuts its light to the photoresistor, then the signal of the photoresistor is LOW because it will not be illuminated, and the ESP32-CAM will take pictures at that time. It will take a short or long time to save the data to the Cloud, depending on the Wi-Fi connection quality, including the speed, bandwidth, etc.

3. EXPERIMENTAL RESULTS

3.1 Physical hardware implementation

The proposed security system utilized an ESP32-CAM development platform with laser detection, and the warning device was assembled according to the design in Section 2 and is realistically described as shown in Figure 4. There are two devices depicted in Figure 4. The device on the left side of Figure 4 is the ESP32-CAM kit, which is utilized to capture images of unauthorized intruders. The device on the right side of Figure 4 is a sensor module used to detect illegal intruders.

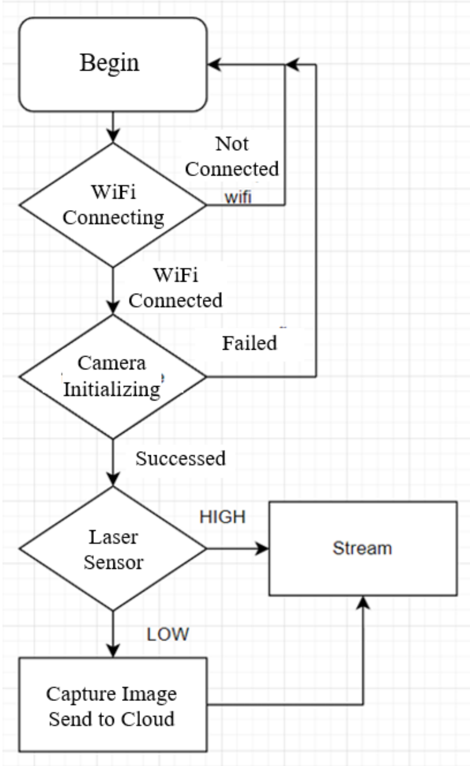


Figure 3. *The software flowchart*

Figure 4. *Physical hardware implementation*

The main components of the device including the ESP32-CAM kit and the ov2640 camera (as depicted in Figure 5), were placed in the camera box as illustrated in Figure 4 (on the left side).

(a) (b)

Figure 5. *Physical hardware implementation*

The ESP32-CAM kit (as in Figure 5(a)) is an affordable and powerful platform that can be used to develop smart projects on Arduino. The kit supports data transfer via Wi-Fi and Bluetooth, and it has more interfaces than its predecessor ESP8266. Espressif Systems released the ESP32 in 2016, a powerful and inexpensive microcontroller built based on TSMC 40nm technology. The ESP32 is equipped with a dual-core 32-bit processor that can be clocked at 80, 160, or 240 MHz. The microcontroller has a special cable for connecting the OV2640 camera, a slot for a microSD memory card, and the ESP32-S chip itself. Images can be stored on an SD card in JPEG format. An adapter fôm UART to USB is needed to connect the module to a computer. The OV2640 camera (as in Figure 5(b)) provides the ability to obtain and analyze images of objects presented in the camera's view due to a microcontroller that works with low-level protocols. Because of this, the module has become popular in addition to the ESP32-CAM. The module consists of a cable for a direct connection to the camera sensor OV2640, which has a wide-angle lens with a viewing angle of 160°. This enables capturing images with a resolution of up to 1600x1200 and a maximum refresh rate of 15 frames per second (FPS).

The sensor module device shown on the right side of Figure 4 is assembled as in Figure 6.

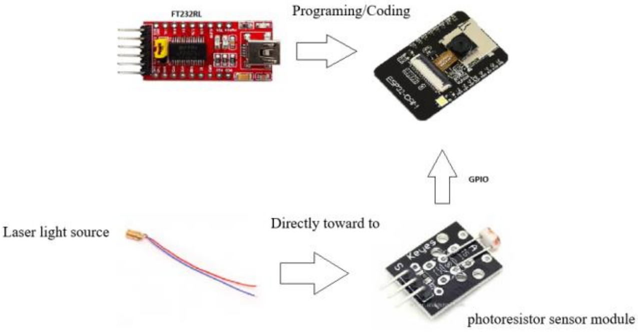


Figure 6. *Assembled sensor module*

3.2 Experimental scenarios and results

In order to prove the proposed system's accuracy, all experiments were done at least 10 times based on the following scenarios:

- Good lighting environment: walking and low-speed running.
- Low lighting environment: walking and low-speed running.

The number of times for correct intruder detection cases out of the total number of actual intrusions is calculated. Experimental results are summarised in Table 1.

Table 1. *Accuracy of the proposed system.*

Environment	Walking [%]	Low Speed Running [%]
Good lighting	100	20
Low lighting	90	40

Under conditions of low-speed operation and good lighting, the success rate was only 20% due to the impact of photoresistance caused by outdoor light. The captured images were blurry and the shots were delayed when the subject (intruders) was out of the camera's view.

Under conditions of low-speed operation and low lighting, the success rate percentage seems higher than the above scenario because the photoresistor is not disturbed by environmental factors. However, the captured images were still blurry and the shots were when the subject (intruders) was out of the camera's view as well.

The quality of dark shots can be improved by the lights, and the photoresistor to noise can also be placed in a darker box to reduce noise. As for the shutter speed, we can change it by adjusting the frequency of the ESP to let the camera shoot faster, but not significantly. To capture fast-moving objects, we can also set up the camera at a wide angle, a wider angle will be easier to capture objects instead of changing the frequency.

Besides, hundreds of experiments were conducted in order to evaluate the proposed system latency to prove the high performance of our proposed system. The latency of the proposed camera-based security system featuring laser detection and warning refers to the time it takes for the system to detect an intrusion, process the information, and issue an alert. The latency average was calculated for latency in the range of a few seconds obtained.

4. CONCLUSION

A Low-Cost ESP32-CAM security system with laser detection and warning via IoT cloud has just been proposed in this paper. Authors have succeeded in designing hardware and software for the proposed system with the results of many experiments showing a good response of detecting unauthorized intruders. The software built on the ESP32-CAM kit is easy to deploy and it can support almost any operation such as data transfer and device verification. The security system hardware operates stably.

The proposed system is simple and compact but good enough for a normal security system with a camera. The imaging hardware is not too clear, but it does support memory cards for storage. Because the proposed system only connects to the IoT Cloud to save abnormal images, the delay between shots is a bit large. However, the model still has some disadvantages such as it has no apps on mobile devices, and produces blurry captured images in dark environments. As a result, the authors plan to further explore the development of a mobile app to simplify monitoring and improve night photography using the ESP's flash, ensuring clearer images, enhancing anti-theft capabilities, and enabling video saving during streaming.

Finally, we acknowledged that improving the accuracy of slow-motion detection in good lighting conditions poses several challenges, especially in applications such as surveillance, sports analysis, and motion capture technology. In the future, we will consider the following solutions to leverage advanced technology, algorithmic enhancements, and system design principles to enhance detection accuracy, such as utilizing high-frame-rate cameras, enhancing Image Processing Algorithms, and adapting Thresholding and Filtering Techniques. Moreover, integrating artificial intelligence and image processing into a camera-based security system featuring laser detection and warning can significantly enhance its effectiveness and responsiveness.

5. APPENDIX

The technical specifications of all hardware components described below indicate the suitability of the hardware design of this proposed system.

- **ESP32-CAM kit:** Responsible for collecting, handling, and processing data by support with the following technical specifications:
  - ✓ Microcontroller: Ai-Thinker ESP32-S.
  - ✓ Operating voltage: 5V.
  - ✓ GPIO communication voltage: 3.3VDC.
  - ✓ SPI Flash: Default 32Mbit.
  - ✓ RAM: 520KB SRAM, 4M PSRAM.
  - ✓ Bluetooth: Standard Bluetooth 4.2 BR/EDR and BLE.
  - ✓ Wi-Fi: 802.11b/g/n/
  - ✓ Support interface: UART, SPI, I2C, PWM.
  - ✓ Support TF card: Support up to 4G.
  - ✓ I/O port: 9.
  - ✓ UART Baudrate: Default 115200 bps.
  - ✓ Image output: JPEG (only supports OV2640), BMP, GRAYSCALE.
  - ✓ Frequency: 1421 ~ 2484 Mhz.
- **FT232RL board:** Responsible for programming the ESP32-CAM kit with UART protocol.
  - ✓ Main IC: FT232RL from FTDI.
  - ✓ Power supply: 5VDC from USB port.
  - ✓ Baudrate: custom adjustable.
  - ✓ DTR: UART TTL Data Terminal Ready pin, usually not used.
  - ✓ RXD: UART TTL receives data receive pin.
  - ✓ TXD: UART TTL transmits data pin.
  - ✓ VCC: 5V or 3.3VDC power supply via Jumper.
  - ✓ CTS: UART TTL hardware flow controls pin.
- **Photoresistor Module KY-018:** helps to detect unauthorized intruders.
  - ✓ Used to measure Laser light source intensity.
  - ✓ Operating voltage 3.3V to 5V.
- **Laser light source:**
  - ✓ Operating voltage: 5V.

6. ACKNOWLEDGMENT

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