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Development of An Iot-Based Security System For Swiftlet Nests Using Esp32-Cam and Pir Sensor

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Abstract – This study focuses on developing an Internet of Things (IoT)-based security system for swiftlet nests using ESP32-CAM and Passive Infrared (PIR) Sensors. The goal is to address the challenges of securing swiftlet nests located in remote areas, which are prone to theft and hard to monitor manually. The system combines motion detection, image capturing, and notification delivery through Telegram when connected to the internet. If the internet connection is unavailable, captured images are stored on a microSD card as an alternative. The research methodology includes the design of both hardware and software, implementation, and system performance testing. Test results show that the PIR sensor effectively detects motion within a 1-5 meter range, and the ESP32-CAM can capture and send images to Telegram in under 10 seconds when the network is stable. The system also reliably stores images on the microSD card when offline. This research highlights the system's ability to improve the security of swiftlet nests efficiently, offering a practical solution for farmers to monitor their nests in real-time without being physically present. The system's flexibility and reliability make it a valuable tool for enhancing the security of agricultural resources.

Keywords: Internet of Things (IoT); ESP32-CAM; PIR Sensor; Swiftlet Nest Security; Telegram Notification

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1. Introduction

Swiftlet farming has become a promising industry, offering significant economic benefits through the high value of swiftlet nest products. These nests, largely made up of swiftlet saliva, are widely used in traditional medicine and cuisine, making them a profitable commodity [1]. However, swiftlet farming presents unique challenges, particularly in securing the nests from theft and unwanted disturbances. Swiftlet nests are typically located in remote areas or specially designed buildings far from residential zones to create an ideal habitat for the birds. These isolated locations make monitoring and security significant concerns for swiftlet farmers [2].

With the advancement of technology, the Internet of Things (IoT) offers innovative solutions to these challenges. IoT enables devices to communicate and function intelligently through internet connectivity, making it suitable for remote monitoring systems. The application of IoT in security systems has proven effective across various domains, from smart homes to industrial applications, providing real-time monitoring and alerts to users [3].

This study aims to develop an IoT-based security system specifically designed for swiftlet nests using ESP32-CAM and Passive Infrared (PIR) Sensors [4], [5]. The system is designed to detect motion, capture images, and send notifications via the Telegram app when connected to the internet [3], [6], [9]. In scenarios where the internet connection is unavailable, the system ensures that captured images are stored on a microSD card, providing a reliable alternative [7], [8].

The significance of this research lies in its effort to meet the specific needs of swiftlet farmers for a cost-effective and reliable security system. By combining hardware and software components, the proposed system offers real-time monitoring capabilities, reduces dependence on physical presence, and minimizes the risk of theft or damage to the swiftlet nests. This study will discuss the development, implementation, and performance testing of the proposed system, while highlighting its practical applications and potential for further innovation in agricultural security technology [11].

2. Literatur Review

The development of Internet of Things (IoT) technology has revolutionized various fields, including security systems, by enabling devices to communicate and function intelligently. IoT-based systems are widely applied to improve the efficiency and effectiveness of real-time monitoring and security solutions, especially in remote and critical environments.

2.1. IoT-Based Security Systems

IoT-based security systems integrate various components, such as sensors, cameras, and communication modules, to provide real-time monitoring and alerts. Previous studies have demonstrated the effectiveness of IoT in detecting unauthorized activities and sending immediate notifications. For example, Kusuma et al. [4] developed a home security system using ESP32-CAM and Telegram, which is capable of detecting motion and sending images within a 3-meter range. However, their system fully relies on internet connectivity to transmit images, which poses limitations in areas with poor network access.

2.2. Use of PIR Sensors

Passive Infrared (PIR) sensors are commonly used in IoT-based systems for motion detection due to their high sensitivity and energy efficiency. These sensors detect infrared radiation emitted by objects, making them ideal for detecting the movement of humans or animals [7]. Research by Desmira et al. [5] showed that PIR sensors are effective in detecting motion within a certain range, highlighting their utility in security systems that require real-time detection.

2.3. The Role of ESP32-CAM in IoT

The ESP32-CAM, a microcontroller with a built-in camera, is known for its flexibility and efficiency in IoT applications. Studies such as those by Hermawan [6] and Aryunita et al. [8] used ESP32-CAM to capture and transmit images, demonstrating its potential for monitoring and security purposes. Its ability to integrate with various platforms, such as Telegram, enhances its practicality for real-time notifications and data sharing.

2.4. Gaps and Innovation

Although IoT-based security systems continue to evolve, several challenges remain. Many existing systems heavily rely on consistent internet connectivity, limiting their reliability in areas with unstable networks. Furthermore, the integration of alternative storage solutions, such as microSD cards, is rarely explored, leaving a gap in improving data redundancy and security [10]. This study addresses these limitations by combining the ESP32-CAM and PIR sensors with dual functionality: sending images via Telegram when online and storing data on the microSD card when offline.

By building on existing literature and addressing these gaps, this research aims to provide an efficient and reliable IoT-based security system for swiftlet nests, ensuring comprehensive monitoring and protection in remote and challenging environments.

3. Research Methodology

This research methodology is designed to develop and test an Internet of Things (IoT)-based security system using ESP32-CAM and Passive Infrared (PIR) Sensors. The study combines both hardware and software design to create a system capable of detecting motion, capturing images, and sending notifications via Telegram, as well as storing images on a microSD card when there is no internet connection. Below are the steps taken in this research.

3.1. System Design

The system design includes two main streams: hardware design and software design. The primary goal of both streams is to ensure the system operates efficiently and meets the research objectives. Below is an overview of the system design:

Hardware Simulation

The hardware design starts with a visual simulation of the swiftlet nest building where the security system will be installed. This visualization ensures the strategic placement of hardware components. The following images show the building design and device installation locations:

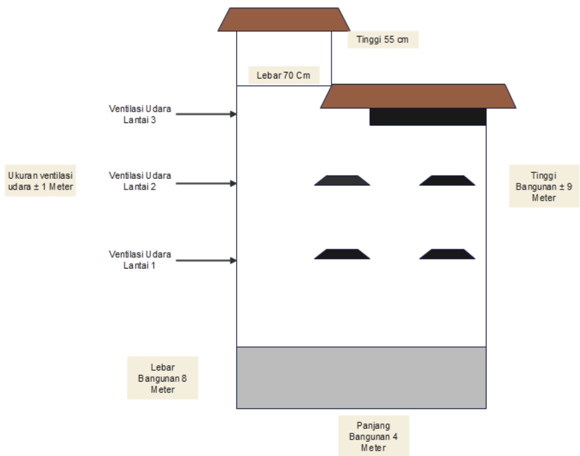

Figure 2.11 shows a visual of the building from the back

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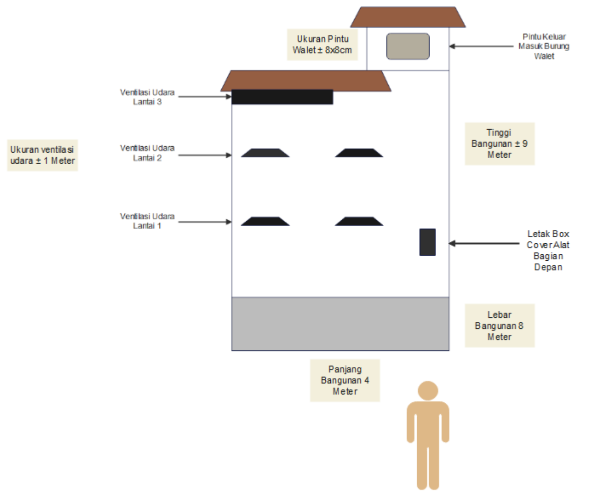

Figure 2.12 shows the visual from the front

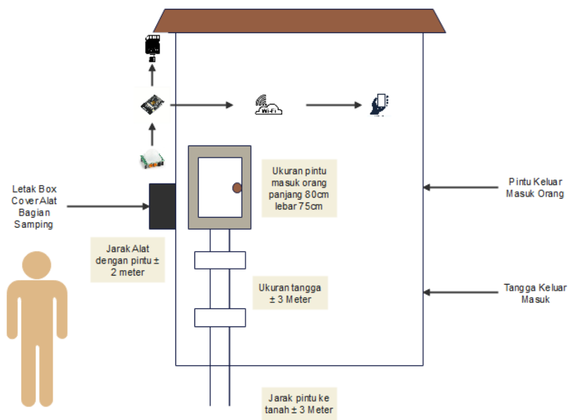

Figure 2.13 shows the visual from the side

The swiftlet nest building consists of three floors with dimensions of 4 meters in length, 8 meters in width, and approximately 9 meters in height. The entrance for humans is about 3 meters from the ground, while the entrance for the swiftlets measures 8x8 cm. The building is equipped with lights and bird sounds powered by PLN electricity, with solar energy as a backup during power outages.

In **Figure 2.13**, the IoT-based security system using ESP32-CAM and PIR (Passive Infrared) Sensors is installed at the left corner of the nest entrance. The PIR sensor works by detecting temperature changes caused by movement from humans or other objects. The PIR sensor's detection range reaches about 5 meters, and its output switches from LOW to HIGH when movement is detected [7].

Hardware Design

The hardware design integrates several main components: the PIR Sensor to detect motion, the ESP32-CAM for capturing images, and the microSD card for storing images when there is no internet connection. **Figure 2.15** shows the system block diagram illustrating the relationship between components.

The **input** consists of the PIR Sensor, which detects temperature changes due to movement around the swiftlet nest, with a detection range of up to 7 meters, and the ESP32-CAM, a microcontroller equipped with a 2 MP camera to capture images based on PIR sensor signals or commands from the Telegram app.

The **process** is handled by the ESP32-CAM, which processes the information from the PIR sensor and captures an image when motion is detected. If connected to the internet, the image is sent to Telegram, but if there is no internet, the image is stored on the microSD card.

The **output** consists of the Telegram app, which receives notifications and images from the ESP32-CAM, allowing users to view and respond to activity around the swiftlet nest, and the microSD card, which stores images when there is no internet connection, with a minimum capacity of 16GB for long-term image and video storage.

Figure 2.16 shows the hardware circuit connecting the PIR Sensor with the ESP32-CAM and microSD card. Each component is connected via jumper cables, ensuring smooth circuit operation.

3.2. System Testing

System testing is conducted to evaluate the performance of each component under real conditions. Testing is done in two main scenarios: first, with an active internet connection, where the system sends images and notifications via Telegram, and second, without an internet connection, where the system stores images on the microSD card. The test results include analysis of image transmission speed, motion detection effectiveness, and the system's data storage capability on the microSD card.

3.3. Use of PIR Sensor

This research develops a system with two main components: hardware and software. The hardware consists of the ESP32-CAM, PIR Sensor, and microSD card, while the software includes programming the ESP32-CAM using Arduino IDE and integrating it with Telegram for notification delivery.

Table 1
presents the specifications of the components used in this research.

Component	NAME / MANUFACTURER	Specification Values
ESP32-CAM	ESP32 (ESPRESSIF)	2 MP Camera, Wi-Fi, Bluetooth
PIR Sensor	Panasonic (PIR-Sensor)	Detection Range 1-5 meters
MicroSD Card	SanDisk	Capacity 16GB

3.4. Data Collection

Data collection is carried out through system performance testing at the swiftlet nest location. The

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equipment used in the testing consists of the ESP32-CAM mounted with a PIR sensor outside the nest, along with the software integrated with the Telegram app to send images and notifications. The testing location is situated in a remote area to assess the system's effectiveness in isolated conditions.

3.5. PIR Sensor Use

System testing is performed in two conditions: first, with an active internet connection and second, without internet connection. The system is tested by activating the PIR Sensor to detect movement around the swiftlet nest, which triggers the ESP32-CAM to capture an image and send it to Telegram if connected to the internet. If there is no internet, the image is stored on the microSD card.

The system testing involves evaluating the ESP32-CAM's capability to capture images under various lighting conditions, both day and night, while also assessing the image transmission speed via Telegram to ensure rapid response time. The PIR sensor is tested for motion detection sensitivity across different distances and angles, with objects placed at varying positions within a range of 1 to 7 meters. Additionally, the Telegram bot is tested to verify its responsiveness to user commands, allowing image capture and motion detection notifications. Lastly, the microSD storage functionality is assessed to ensure images are stored when the internet is unavailable, with performance tests conducted to evaluate storage and retrieval speed in offline conditions [12].

3.6. Data Analysis

The data collected during testing will be analyzed to assess the overall performance of the system. The results from the ESP32-CAM, PIR Sensor, and Telegram bot will be compared with predefined criteria, such as response time, detection accuracy, and notification delivery accuracy.

3.7. Validation and Evaluation

After testing, the results obtained from the system implementation will be evaluated to ensure that the system functions as intended. The evaluation will be based on the effectiveness of the system in detecting motion, the speed of image transmission, and the successful storage of images on the microSD card when no internet connection is available.

4. Results and Discussion

This study evaluated the performance of an IoT-based security system using ESP32-CAM and Passive Infrared (PIR) Sensors for detecting motion, capturing images, and transmitting images and notifications via Telegram. The system was tested under two primary conditions: with an active internet connection and without an internet connection, where images were stored on a microSD card. The following section presents the test results and a discussion on the system's performance.

4.1. Test Results

System performance was evaluated by testing each component (ESP32-CAM, PIR Sensor, and Telegram app) under two different scenarios. The first scenario involved an active internet connection, where the system transmitted images and notifications directly to the Telegram app. The test results indicated that the ESP32-CAM was capable of capturing images with good clarity under various lighting conditions, both during the day and at night, consistent with previous studies demonstrating the effectiveness of ESP32-CAM in security applications [4]. Image transmission to Telegram was completed in less than 10 seconds under stable network conditions, aligning with the findings of Qasim et al. [9], who reported efficient data transfer in IoT-based security systems. However, during periods of network instability, image transmission times exceeded 1 minute, which is similar to the network-dependent delays observed in prior research [7].

In the second scenario, where there was no internet connection, the system successfully stored images on the 16GB microSD card. The image storage process was smooth, and the images were captured clearly, even in the absence of an internet connection. The PIR sensor also performed effectively, detecting motion within the specified range of 1 to 5 meters, which is consistent with the detection accuracy reported in previous works [5].

4.2. Discussion

The ESP32-CAM functioned effectively in capturing images. The built-in 2 MP camera provided sufficiently clear images for swiftlet nest monitoring. However, the image transmission via Telegram was affected by network conditions. With a stable internet connection, image transmission occurred in less than 10 seconds; however, with unstable network conditions, the transmission time exceeded 1 minute. This illustrates that while the ESP32-CAM is capable of good-quality image capture, its data transmission performance is highly reliant on the quality of the internet connection.

The PIR sensor successfully detected motion with high sensitivity within the range of 1 to 5 meters. Beyond this range, particularly at angles such as 150°, motion detection accuracy decreased. This finding is consistent with the research by Setianto (2022), which indicates that the detection range of PIR sensors is strongly dependent on the position of the object and the sensor's angle of detection. Despite slight reduction in sensitivity at longer ranges, the PIR sensor provided fast and reliable motion detection notifications.

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The microSD card storage functionality was tested and found to operate efficiently in the absence of an internet connection. The 16GB microSD card was capable of storing a considerable number of images and videos over an extended period without issues. This feature proved useful as a backup in situations where real-time data transmission via Telegram was not feasible.

The system was effectively integrated with the Telegram app, enabling users to receive real-time notifications and images. Testing of the Telegram bot functionality confirmed that the system responded promptly to user commands, such as triggering image capture and sending notifications when motion was detected. This integration facilitated remote monitoring of the swiftlet nests, eliminating the need for physical presence at the location.

4.3. Limitations and Potential Developments

While the system proved effective in detecting motion and transmitting images via Telegram, certain limitations were identified. A primary limitation is the reliance on internet connectivity, which can impact the speed of image and notification delivery. To address this issue, future development could incorporate enhanced storage solutions and the use of alternative networks, such as cellular data, to increase the reliability and stability of data transmission.

Furthermore, future improvements could include the integration of multiple cameras to broaden the monitoring area and the implementation of machine learning algorithms to enhance motion analysis. For example, distinguishing between human and animal movements would improve the system's accuracy in detecting potential threats.

Overall, the IoT-based security system utilizing ESP32-CAM and PIR sensors has demonstrated its capability to secure swiftlet nests efficiently. The system can detect motion, capture images, and send real-time notifications, as well as store images on a microSD card when no internet connection is available. Despite challenges related to internet quality, the system shows significant promise for deployment in remote areas. Future advancements could focus on improving system stability, increasing coverage, and enhancing data transmission reliability.

5. Conclusion

This study successfully developed and tested an innovative IoT-based security system using ESP32-CAM and Passive Infrared (PIR) Sensors to significantly enhance the security of swiftlet nests. The system demonstrated its ability to detect motion, capture images, and send real-time notifications through the Telegram app when connected to the internet. When internet access is unavailable, the system reliably stores images on a microSD card, ensuring uninterrupted monitoring and security. Test results confirm the system's effectiveness under various conditions, with the PIR sensor successfully detecting motion within a range of 1 to 5 meters, and the ESP32-CAM capturing clear and actionable images.

Real-time integration with the Telegram app enables swiftlet farmers to remotely monitor their nests, providing critical alerts and images without being physically present. While the system is effective, its performance is impacted by internet quality, with transmission delays occurring under weak network conditions. However, the use of microSD card storage offers a robust backup solution, ensuring data is preserved even when direct transmission fails.

This research underscores the transformative potential of IoT in advancing security solutions, particularly in remote and hard-to-reach environments. The findings point to the urgent need for enhanced, cost-effective security systems in agriculture. Future developments should focus on improving system resilience, expanding coverage with additional cameras, and leveraging machine learning to enable smarter, more accurate threat detection. The flexibility and reliability of this system make it an essential tool for securing swiftlet nests, with vast potential for further applications in agriculture and remote monitoring.

References

[1] H. Muliati and B. Dawiya, "Studi usaha sarang burung walet dalam meningkatkan pendapatan desa," *J. Mirai Manag.*, vol. 7, no. 1, pp. 182–199, 2022.

[2] B. Sokhi and E. A. Kadir, "Sistem keamanan rumah walet menggunakan sensor cahaya dan sensor getaran diintegrasi dengan SMS notifikasi," *IT J. Res. Dev. (ITJRD)*, vol. 3, no. 1, pp. 1–10, 2019.

[3] R. Rifandi et al., "Raspberry dengan aplikasi Telegram berbasis," *J. PROSISKO*, vol. 8, no. 1, pp. 19–20, 2021.

[4] H. A. Kusuma, S. B. Wijaya, and D. Nusyirwan, "Sistem keamanan rumah berbasis ESP32-CAM dan Telegram sebagai notifikasi," *Infotronik: J. Teknol. Inf. Elektron.*, vol. 8, no. 1, p. 30, 2023.

[5] D. Desmira et al., "Pendeteksi gerakan menggunakan sensor PIR," *J. Syst. Elektron.*, vol. 7, no. 2, pp. 45–51, 2020.

[6] Y. Hermawan, "Rancang bangun kamera portabel pemantau ruang brankas berbasis IoT menggunakan ESP32 Camera," *Teknika*, vol. 1, no. 1, pp. 32–42, 2023.

[7] S. T. Setianto, "Rancang bangun sistem keamanan rumah menggunakan sensor PIR dan SMS GSM berbasis Arduino," *J. Fis. Otomatis*, vol. 1, no. 1, pp. 30–36, 2022.

[8] F. Aryunita, N. Rasjid, and M. F. Mansyur, "Rancang bangun sistem monitoring keamanan kandang ayam broiler menggunakan ESP32-CAM berbasis IoT dengan aplikasi Android," *J. Inform. Teknol. Elektro Terap.*, vol. 12, no. 1, pp. 15–25, 2024.

[9] H. H. Qasim, A. E. Hamza, H. H. Ibrahim, H. A. Saeed, and M. I. Hamzah, "Design and implementation home security system and monitoring by using wireless sensor networks WSN/internet of

e-ISSN: 2723-3944

things IOT," *Int. J. Electr. Comput. Eng.*, vol. 10, no. 3, pp. xx–xx, Jun. 2020.

[10] A. A. Muradova and A. F. Khaytbaev, "Analysis of the reliability of the components of a multiservice communication network based on the theory of fuzzy sets," *Telkomnika (Telecommun. Comput. Electron. Control)*, vol. 19, no. 5, pp. 1715–1723, 2021.

[11] R. H. Abdullah et al., "Study of adsorption characteristics of a low-cost sawdust for the removal of Direct Blue 85 dye from aqueous solutions," *Indones. J. Chem.*, vol. 18, no. 4, pp. 724–732, 2018.

[12] G. Grispos, W. B. Glisson, and T. Storer, "Recovering residual forensic data from smartphone interactions with cloud storage providers," in *The Cloud Security Ecosystem*, R. Ko and K.-K. R. Choo, Eds. Boston, MA, USA: Syngress, 2015, pp. 347–382. doi: 10.1016/B978-0-12-801595-7.00016-1.

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