(IJECAR) International Journal of Engineering Computing Advanced Research
Vol. 2, No. 1, Oktober 2025 pp. 11~18

Design Of an Internet of Things (IoT) Based Security System Using Esp32 Cam and Passive Infrared Receiver (PIR) Motion Sensor in the Home Environment

Argea Rama Bagaskara[1], Ajib Susanto[2]
[1,2]Department of Informatics Engineering, University of Dian Nuswantoro, Semarang, Indonesia, 50131

Article Info:

Keywords:

Security Systems
Internet of Things
PIR Motion Sensor
ESP32-CAM
Telegram Bot

ABSTRACT

Environmental security is an essential aspect to reduce criminal activities at home, especially amid the increasing incidents of crime. Automated security systems utilizing IoT technology, such as PIR motion sensors and ESP32-CAM, integrated with CCTV, prove to be an effective solution. The choice of Telegram application as the notification platform provides flexibility and additional security, as it is open source. This research adopts a prototype method with stages of needs analysis, prototype development, evaluation, coding, testing, assessment, and system usage. The Motion Detection System with Message Notifications in Hazardous Environments has been successfully built and tested. Users can control it through the Telegram bot, set timers via Arduino IDE, with the note of keeping the security of the BotFather token. Stable internet connection is required, and the PIR sensor is effective within a range of 1m-5m. The objective of this final project is successfully achieved with the development of an IoT-based security system, creating a safe and efficient environment.

Author Correspondence:

Ajib Susanto,
Department Informatics Engineering
Faculty of Computer Science
University of Dian Nuswantoro
Email: ajib.susanto@dsn.dinus.ac.id

1. INTRODUCTION

Neighborhood safety plays a crucial role in reducing crime, especially at home. In this context, developing an optimal security system is the key to achieving this effectiveness [1], [2]. However, the Banyumanik District area, Semarang City, faces a serious problem related to car theft, with one perpetrator registering six crimes. The increase in theft cases in Semarang City, especially ahead of Eid 2023, reached 100-120 cases per month, compared to an average of 70 cases per month previously [3].

To overcome this challenged, there are two types of security systems: manual and automatic. Automated security systems, which use technologies such as motion sensors and CCTV, demonstrate high effectiveness. The choice of the Telegram application as a notification platform was based on its advantages as open source, allowing additional development. An IoT-based security system [1], [4], [5], [6] is a solution with the ability to monitor and control home conditions in real-time via the internet. This system utilizes PIR motion sensors and ESP32-CAM [7], [8], [9], [10], [11] to detect movement and provide visual notifications via Telegram [8], [12], [13], [14], creating a safer and more efficient environment. Thus, the author succeeded in building a "Motion Detection System with Message Notifications in the Home Environment Using IoT- Based Passive Infrared Receiver (PIR) and Esp32-Cam Motion Sensors Using Telegram Bots.

At the Literature Study stage, we collected references from various journals, articles, and ebooks available on the internet. One example of a significant journal reference for compiling a final assignment is "Implementation of PIR Sensors in Microcontroller-Based Electronic Equipment." This reference is an important contributor in developing the content of the Final Project. Meanwhile, the Observation stage was

carried out by directly observing how the community managed the security system in Tembalang District, Semarang City. Direct interviews were conducted with the RT to obtain information regarding security in the surrounding environment, making this observation a valuable source of data in research.

2. METHOD

2.1. Research Instrumentation

The initial step in the construction of a motion detection system prototype for the home environment involves planning and describing the activities to be performed. This aims to organize various goals and purposes so that the achievement of the goals desired by the author can be directed and efficient. In developing a Motion Detection System tool [15], [16] using a PIR Motion Sensor [7], [9], [12], [17], ESP32-CAM [10], [11], and Notifications for the Telegram Application, the hardware plays a role as input and output control, while the software supports writing programs in Arduino.

The hardware required to implement a motion detection system includes components and modules such as ESP32-CAM, Passive Infrared Receiver (PIR) Sensor, RTC Module, Breadboard, Jumper Cables, Micro USB, and Android / Iphone Smartphone. Meanwhile the software that supports the development of this system is Telegram, where bots will be created to control the tool. In addition, the Arduino IDE is used as a platform for writing program code on the ESP32-CAM microcontroller [18], [19], with the aim of integrating the program into a series of microcontroller devices.

2.2. Proposed Method

The prototype method is a system development approach that starts from collecting customer requirements to creating a mockup or prototype. The main focused is understanding user needs from the start as in Figure 1.

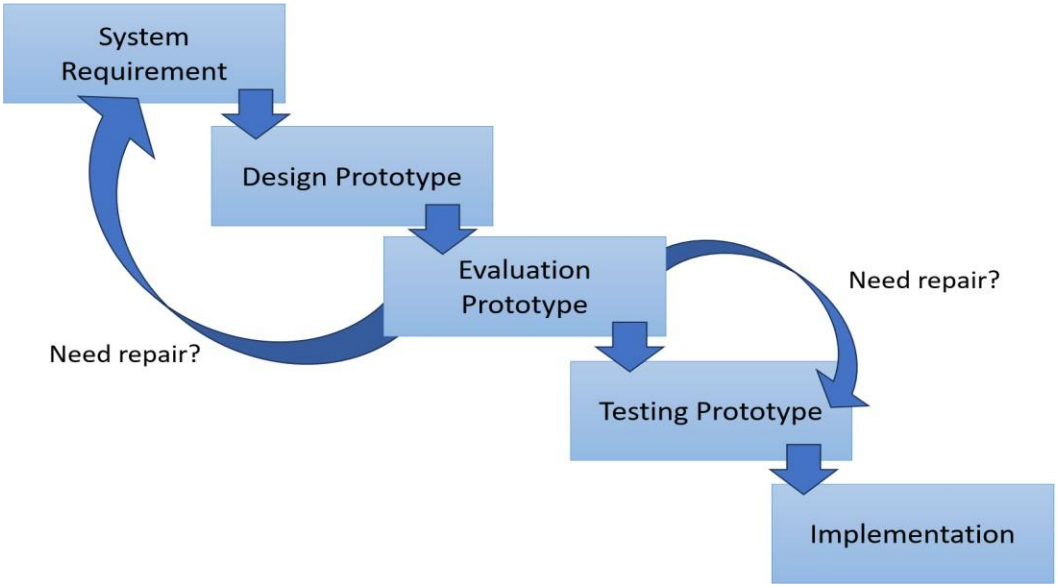

Figure 1 Proposed Method

1. Needs analysis

In the needs analysis stage, the first step in developing an IoT-based security system for the home environment in Tembalang District, Semarang City is to identify specific security needs. This process involves observing similar applications and analyzing how they overcome security challenges, taking into account in the problem boundaries highlighted in this research.

2. Make a prototype

At this stage, designing an IoT-based security system emphasizes program flow and interaction with users. This prototype serves as a visual representation of the initial design, allowing initial assessment and user feedback on the security offered by the system. This prototype was created using block diagrams, flow charts, and a series of security system schemes in an IoT-based home environment.

3. Evaluate the prototype

At this stage, an in-depth evaluation is carried out to ensure that the security design meets previously established standards and expectations.

4. Coding the system

Once the prototype is approved, the next step is to code the system, translate it into a suitable programming language, and integrate it with hardware such as the ESP32-Cam and PIR sensors [20], [21]. The implementation process must ensure that each stage considers previously identified security needs.

5. System testing

At this stage, system security testing is the next stage which involves testing sensor readings, tool functions, and testing telegram responses. First, the PIR sensor is tested to ensure movement detection accuracy. Then, the tool's functionality was thoroughly evaluated, focusing on the integration of the PIR sensor, ESP32-Cam, and Telegram notification module. The system's response via Telegram was tested to measure the speed and reliability of notifications after detecting suspicious movements. Overall integration testing is performed to ensure efficient operationality in real security scenarios. System security [20] is tested to assess resistance to potential threats and manipulation. Finally, the suitability of the system to the problem constraints is verified for successful integration. With this series of tests, it is hoped that the system can be implemented effectively, providing an optimal level of security in accordance with development objectives.

6. System evaluation

At this stage, user evaluation becomes an important step to obtain practical feedback regarding system security. By ensuring the system meets user expectations and needs, the next step is to deploy an IoT-based security system that has been tested and approved, making it ready for use in everyday life in the specified home environment.

7. Using the system

At this stage, the software that has gone through the testing process and received approval is ready to be used.

2.3. Experimentation and Testing Methods

This test plan involves component functional testing, program simulation, and overall testing to ensure data validity and tool operationality. PIR sensor testing involves reading sensors connected to the ESP32-Cam and Telegram, with a focus on detecting movement in the sensor's coverage area. Next, testing will be carried out on the tool's function by placing the sensor in a box at the front or back of the house, connecting it to the ESP32-Cam, and sending notifications to Telegram. This tool can also be deactivated according to home conditions and has a timer option to automatically detect the presence of people around the house. Testing Telegram responses involves giving a start command to display results according to the selected command. This entire testing is geared towards ensuring the operationality and effectiveness of the developed IoT-based security tools

3. RESULTS AND DISCUSSION

The next step in developing this project is to carry out a needs analysis to build an Internet of Things (IoT) based security system around the home environment using the ESP32 Cam and Passive Infrared Receiver (PIR) sensors. The main focused of this system is to detect movement around the house and provide notifications in the form of photos via the Telegram application to users. This research stage will involve a series of steps that describe the detailed system design. Various stages will be undertaken in this process, including:

Need	Description
Motion Detection	The system must be able to detect human movement at various distances and be able to provide notifications via the Telegram application when it detects movement
Shooting	The system must use the ESP32-Cam to capture images in response to motion detection
Real Time Clock (RTC) Modul	The module must ensure correct timing of each image capture and notification.
Telegram Bot Integration	The system must be integrated with the Telegram Bot to provide notifications and monitoring.

Table 1 Table System Requirements Analysis

The device design stage is a crucial step that involves transforming concepts from previous analysis into concrete designs to improve home security based on the Internet of Things (IoT). With the main aim of building a security system using the ESP32 Cam and PIR sensors, the design of this tool focuses on the optimal

arrangement of the two devices to achieve synergistic integration. The following is the design of an Internet of Thoughts (IoT) based security system using an ESP32 cam and a Passive Infrared Receiver (PIR) motion sensor in a home environment.

A block diagram is a graphical representation of the function of each component and its signal flow. Block diagrams provide information regarding the physical structure of the system. This is an important element in design, helping to understand the overall working principle.

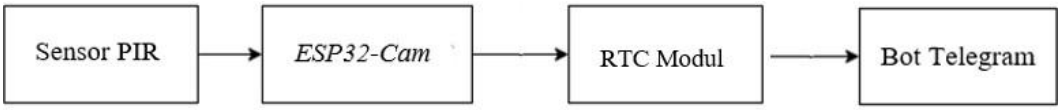

Figure 2 Block Diagram Design

Figure 2 above is a block diagram for a motion detection tool using a PIR sensor and ESP32-Cam. Here's the explanation:

1. Passive Infrared Receiver (PIR) Sensor . Used as a motion detection sensor around the area where the device is installed.
2. ESP32-Cam. Used as a camera to record and take pictures along with the date and time.
3. RTC Modules. Used as a Real Time Clock or digital timing.
4. Telegram Bots. Used as a monitoring medium in the system .

This scheme is used to understand and explain the entire model of a motion detection device using a Passive Infrared Receiver (PIR), ESP32-Cam, RTC Module sensor that the author created. The following is the circuit schematic as visualized in Figure 3.

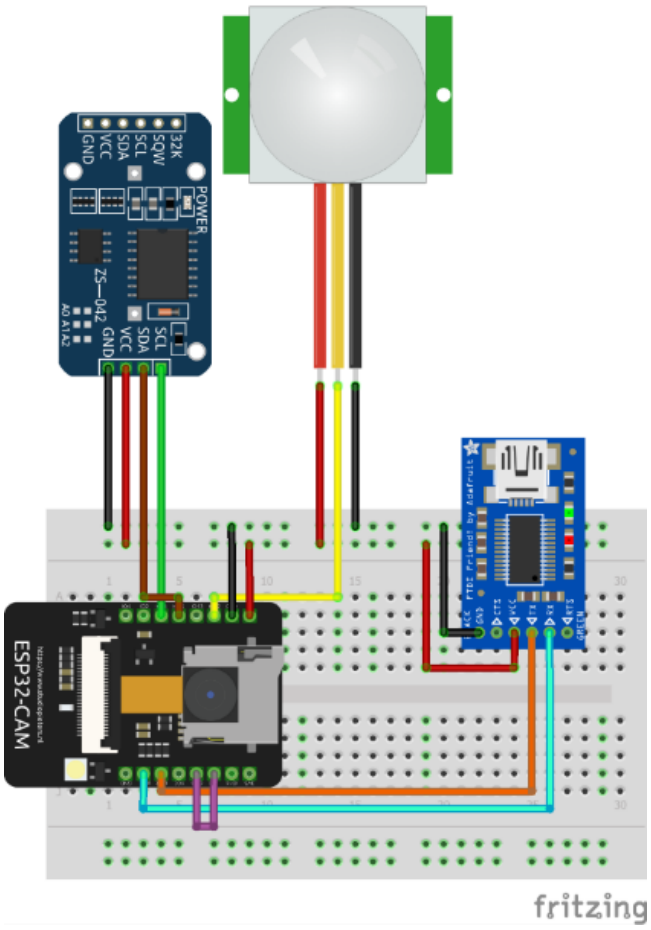

Figure 3 Whole Circuit Schematic

Figure 3 above is a schematic of the entire series of tools that the author created. The following is an explanation of the entire circuit schematic and its functions:

1. The Passive Infrared Receiver (PIR) sensor is used to detect movement around the area where the device is installed.
1. ESP32-Cam is used to capture the detected image.
2. FTDI (Future Technology Devices International) is used to program the ESP32-Cam.
3. RTC (Real Time Clock) is used to store time or digital timing.
4. Breadboard is used to design a simple electronic circuit. The breadboard will later be prototyped or tested without having to solder it.

The software design aims to meet the needs in creating a controller application using the Telegram bot on a smartphone and the Arduino IDE. The Telegram app, accessible for free via the Play Store for Android users and the App Store for iOS users, as well as via desktop with a dedicated app or the official website, ensures accessibility across multiple platforms. Using Telegram features, the author creates a bot that is set up with tokens for the functions to be implemented in the program. The bot profile view is depicted, which is used to receive notifications. To code the ESP32-Cam, the Arduino IDE software is used, which allows programming via C/C++ syntax. The Arduino IDE, downloadable for free from the official Arduino website, is presented, and is used to organize functions through programming syntax, making it a key element in holistic software design.

Motion Detection Systems are one of the first protective features that maintain the physical security of the home. One type of technology that can be used to increase security is by using a sensor. The sensor used in this research is a Passive Infrared Receiver sensor, and also uses an ESP32-Cam microcontroller. ESP32-Cam will send notifications to Telegram when the Passive Infrared Receiver sensor detects conditions around the house in real time. The ESP32-Cam will include a script which aims to run this system properly. ESP32-Cam has provided several IDEs (Integrated Development Environment) in its operating system installation. The script that will be implemented uses the C/C++ programming language, then the script will be run on the Arduino IDE [22], [23]. The following is the script for the system as in Figure 4.

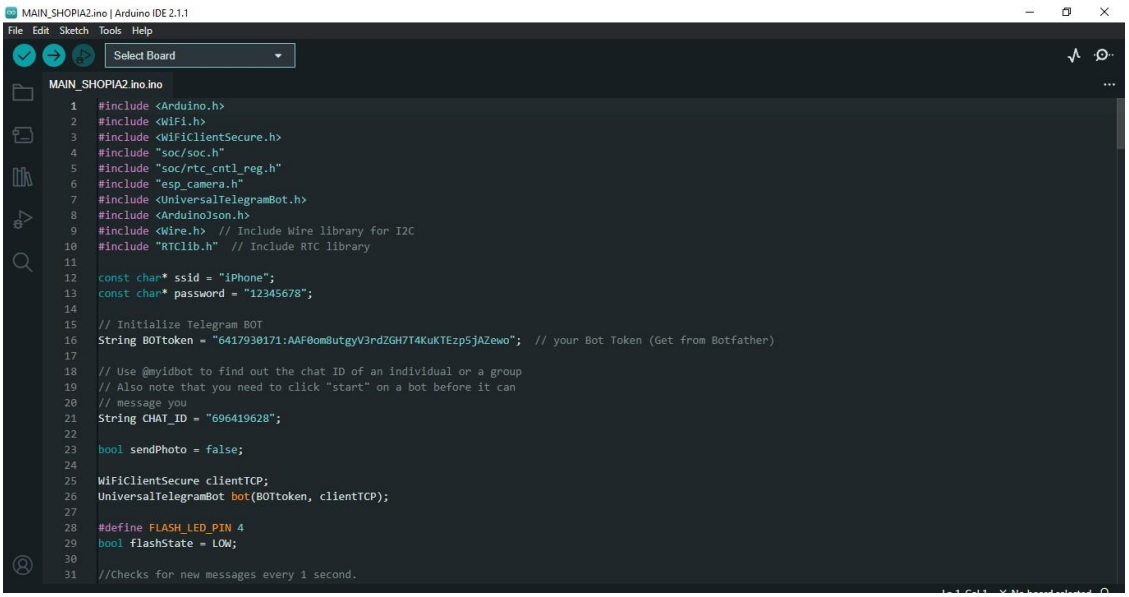

Figure 4 Source code Arduino IDE

Telegram application testing is carried out to find out whether the features work well or not.

Testing Activities	Expected Realization	Test Results
/Start	Features appear on the bot	Succeed
/photo	ESP32-Cam takes photos manually	Succeed
/flash	ESP32-Cam turns on the flash	Succeed

Table 2 Telegram application testing

PIR sensor characterization is carried out by measuring the sensor detection distance. Distance measurements are carried out to determine the maximum distance so that the sensor was able to detect the situation when another person enters the front area of the house. Distance measurements (m) are carried out using a meter. The measurement results can be seen in the following Table 3.

Object	Object Distance	Telegram Notification	Description (Object)
Man	1m	Succeed	Detect
Man	2m	Succeed	Detect
Man	3,5m	Succeed	Detect
Man	4m	Succeed	Detect
Man	5m	Succeed	Detect
Man	6,5m	Not sent	Not Detecting
Man	8m	Not sent	Not Detecting

Table 3 Sensor distance testing

The results of testing the motion detection feature by giving the command "/photo" will get a notification in the form of an image. At night you can use the "/flash" feature to turn on the flash and automatically send the image as seen in Figure 5.

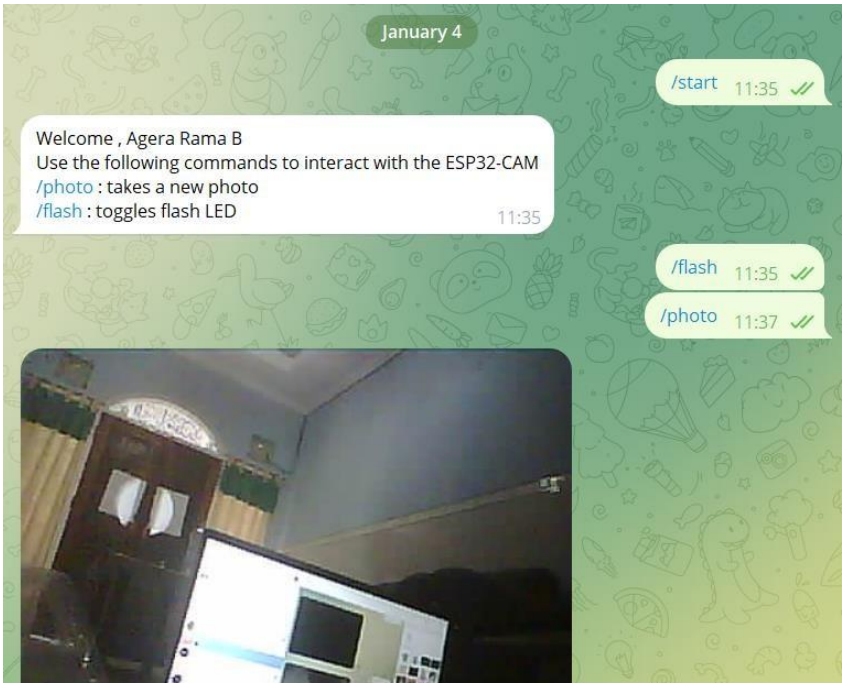

Figure 5 Notifications that come to Telegram

5. CONCLUSION

Based on the results of discussion and testing of the system, there are several conclusions. This Motion Detection System with Message Notifications in Dangerous Environments Using PIR Motion Sensors and IoT-Based ESP32-Cam can run well according to the required functions. This system can be activated or deactivated according to the home owner's wishes by sending a message via a telegram bot and can be given a timer via the Arduino IDE. Tokens obtained from BotFather must not be distributed to other people to maintain system security. In testing the tool requires a stable internet connection so that the system runs smoothly. At a distance of more than 6.5m the PIR sensor cannot detect and send notifications to Telegram. Meanwhile, at a distance of 1m – 5m, the PIR sensor can detect and send notifications to the home owner's Telegram. Meanwhile, the objectives of this final project were fulfilled with the successful development of an IoT-based security system using ESP32 Cam and PIR sensors. This system allows remote access and sending notifications via the Telegram

application, according to predetermined purposes. ❒

Based on the conclusions above, motion detection with message notification using the PIR Motion Sensor and ESP32-Cam can be developed further. For future research, no the ESP 32 Cam Module there is an SD card

slot which in the future can be used for temporary offline storage when the ESP 32 Cam cannot receive or get an internet connection. To overcome the problem of an unstable internet connection, you can alternatively use the GSM SIM800l module. For the development of this tool, the system should not only be controlled from Telegram messages, but also via incoming calls via cellphone, to anticipate if the user is not connected to the internet network. Based on the literature review, the design, manufacturing, programming, and testing stages, the author provides several research recommendations, including the addition of an LCD panel to display data and the installation of LEDs to monitor tool performance.

REFERENCES

[1] S. Mabasha, S. R. Kamini, S. R. Babu, and A. H. SHAIK, "Enhancing Home Security through an Android-based Door Security System using IoT Technology," Aug. 08, 2023. doi: 10.21203/rs.3.rs-3163015/v1.

[2] S. Adhya and G. Sen, "IOT Based Home Security System," in *2023 7th International Conference on Electronics, Materials Engineering and Nano-Technology, IEMENTech 2023*, Institute of Electrical and Electronics Engineers Inc., 2023. doi: 10.1109/IEMENTech60402.2023.10423552.

[3] S. Aisyah, Z. Hidayah, D. Juniadi, E. P. Purnomo, A. M. Wibowo, and R. Harta, "Transforming Smart City Governance for Quality of Life and Sustainable Development in Semarang City, Indonesia," *International Journal of Sustainable Development and Planning*, vol. 19, no. 9, pp. 3443–3452, Sep. 2024, doi: 10.18280/ijsdp.190914.

[4] O. Taiwo and A. E. Ezugwu, "Internet of Things-Based Intelligent Smart Home Control System," *Security and Communication Networks*, vol. 2021, pp. 1–17, Sep. 2021, doi: 10.1155/2021/9928254.

[5] P. J. Reginald, "Smart Security Surveillance System Using IoT PROJECT REPORT Under the Esteemed Guidance of DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING," 2024.

[6] H. Sabit, "Artifical Intelligence-Based Smart Security System Using Internet of Things for Smart Home Applications," *Electronics (Basel)*, vol. 14, no. 3, p. 608, Feb. 2025, doi: 10.3390/electronics14030608.

[7] Nr. Reddy, M. Prasad, and A. Professor, "ESP32-CAM PIR MOTION DETECTOR WITH PHOTO CAPTURE," *Journal of Engineering Sciences*, vol. 14, no. 6, 2023, [Online]. Available: www.ijariie.com

[8] H. Kurniawan and S. Hariyanto, "Designing Home Security With Esp32-Cam and IoT-Based Alarm Notification Using Telegram," *bit-Tech*, vol. 6, no. 2, pp. 95–102, Dec. 2023, doi: 10.32877/bt.v6i2.932.

[9] R. L. Avalareddy, B. Priya Makala, P. Tokala, P. Maradani, V. R. Prabha K, and M. Kumar D, "ESP32-CAM-based Wireless Human Detection System with PIR Sensor and Instant Alerts via GSM and Blynk App," in *2025 5th International Conference on Trends in Material Science and Inventive Materials (ICTMIM)*, IEEE, Apr. 2025, pp. 784–788. doi: 10.1109/ICTMIM65579.2025.10988057.

[10] A. R. Lellapati, B. K. Pidugu, M. S. R. Rangari, G. P. Acharya, and V. Jayaprakasan, "Development of Advanced Alerting System using Arduino interfaced with ESP32 CAM," in *Proceedings of 4th International Conference on Cybernetics, Cognition and Machine Learning Applications, ICCCMLA 2022*, Institute of Electrical and Electronics Engineers Inc., 2022, pp. 261–266. doi: 10.1109/ICCCMLA56841.2022.9988762.

[11] W. Bagye *et al.*, "COMPARISON OF VARIOUS TYPES OF PIR MOTION SENSORS FOR NODEMCU ESP32 CAM IMAGE CAPTURING DEVICES," *Jurnal Informatika & Rekayasa Elektronika)*, vol. 7, no. 2, 2024, [Online]. Available: http://e-journal.stmiklombok.ac.id/index.php/jireISSN.2620-6900

[12] H. Hamuda, "Optimisation of ESP32-Cam-based Smart Security Using Fingerprint and PIR Sensor with Telegram App Notification," *Lovelace Journal of Information System, Security, Education and Network Artificial Intelligence*, 2025, [Online]. Available: https://doi.org/.....

[13] N. Raghu, I. Miah, and A. B. R. Tonmoy, "Ultrasonic Sensor Based Door Security Camera with Wireless Data Transfer in Telegram Bot Using WIFI," in *Proceedings of the International Conference on Intelligent and Innovative Technologies in Computing, Electrical and Electronics, ICIITCEE 2023*, Institute of Electrical and Electronics Engineers Inc., 2023, pp. 402–405. doi: 10.1109/IITCEE57236.2023.10090954.

[14] P. Samuda, K. Sivachandar, N. G. Praveena, C. Nithiya, D. Kamalesh, and C. Lokesh, "Low-cost

Prototype for IoT-based Smart Monitoring through Telegram," in *Proceedings - 5th International Conference on Smart Systems and Inventive Technology, ICSSIT 2023*, Institute of Electrical and Electronics Engineers Inc., 2023. doi: 10.1109/ICSSIT55814.2023.10061155.

[15] V. Arinde and L. Idowu, "Multi-sensor Intrusion Detection System," May 2024, [Online]. Available: http://arxiv.org/abs/2406.05137

[16] V. Rajashekhar, J. E. Rohith, and P. R. Sankpal, "Smart motion Detection and Location tracking system for enhanced security applications using LoRa," in *Proceedings of the 2nd International Conference on Intelligent and Innovative Technologies in Computing, Electrical and Electronics, ICIITCEE 2024*, Institute of Electrical and Electronics Engineers Inc., 2024. doi: 10.1109/IITCEE59897.2024.10467767.

[17] K. Ingale, A. Jadhav, Y. Kolekar, S. Kanse, and T. Jadhav, "Advance Smart Cam PIR Surveillance," in *Proceedings of 8th International Conference on Trends in Electronics and Informatics, ICOEI 2025*, Institute of Electrical and Electronics Engineers Inc., 2025, pp. 195–202. doi: 10.1109/ICOEI65986.2025.11013426.

[18] H. Sabit, "AI-Based Smart Security System Using IoT for Smart Home Applications," Jan. 27, 2025. doi: 10.20944/preprints202501.1887.v1.

[19] M. Uthman Azlan and M. Shamian Zainal, "An IoT Based Home Security System With ESP32, Video Monitoring, and Blynk Integration," vol. 5, no. 1, pp. 238–244, 2024, doi: 10.30880/peat.2024.05.01.024.

[20] N. Nikhare, K. Pelne, T. Parkhi, A. S. Raza, K. Kalbande, and A. Bais, "Innovative Home Security Systems: A Comparative Analysis of IoT-Driven Solutions," in *Proceedings - 3rd International Conference on Advancement in Computation and Computer Technologies, InCACCT 2025*, Institute of Electrical and Electronics Engineers Inc., 2025, pp. 922–927. doi: 10.1109/InCACCT65424.2025.11011476.

[21] S. Gayathri, A. S. Prasad, H. D. Niteesh, K. T. Naik, S. Hurakadli, and R. Vishal, "Low Cost IOT Based Smart Monitoring System," in *IEEE International Conference on Recent Advances in Science and Engineering Technology, ICRASET 2024*, Institute of Electrical and Electronics Engineers Inc., 2024. doi: 10.1109/ICRASET63057.2024.10895461.

[22] Ms. J. Nulyn Punitha Markavathi, S. N, V. M.R, V. M, and P. M, "Real-Time Traffic Density Monitoring and Adaptive Signal Control Using YOLOv8 and Arduino-Based LED System," in *2024 9th International Conference on Communication and Electronics Systems (ICCES)*, IEEE, Dec. 2024, pp. 227–232. doi: 10.1109/ICCES63552.2024.10859969.

[23] Permana langgeng wicaksono ellwid putra, C. A. Sari, and F. O. Isinkaye, "SECURE TEXT ENCRYPTION FOR IOT COMMUNICATION USING AFFINE CIPHER AND DIFFIE-HELLMAN KEY DISTRIBUTION ON ARDUINO ATMEGA2560 IOT DEVICES," *Jurnal Teknik Informatika (Jutif)*, vol. 4, no. 4, pp. 849–855, Aug. 2023, doi: 10.52436/1.jutif.2023.4.4.1129.