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DEVELOPMENT AND OPTIMIZATION OF A REAL-TIME CAMPUS SECURITY SURVEILLANCE SYSTEM USING ARDUINO AND CCTV CAMERA

Ola David Egbe[1], Egba Fraser Anwaitu (Ph.D)[2], Oruan Memoye Kepeghom (Ph.D)[3]
[1,2&3]Department of Computer Science Education, Federal College of Education (Technical), Omoku, Rivers State Nigeria.

oladavidegbe@gmail.com, +2347036106989

ABSTRACT

This project presents the development and optimization of real-time campus security survillance system leveraging Arduino technology and CCTV cameras to enhance campus safety and security. The system integrates hardware components, including Arduino Uno board, Wi-Fi modules cameras, motion sensors and SD card to achieve seamless operation. PIR sensors detect motion and triggers the Arduino to adjust the camera's position and activate recording. Machine algorithm such as k-means clustering was employed for anomaly detection, enabling the system to identify suspicious activity and send real-time alerts to designated devices. The system's accuracy is consistently high across tests ranging from 94.75% to 98.75%. Precision shows the system is generally good at minimizing false positive, though with some variability. Recall values suggest that the system effectively detect most motion event. The implementation of the system enhances campus security by providing real-time alerts and efficient monitoring.

Keywords: Arduino Uno microcontrollers, CCTV cameras, Surveillance, security

INTRODUCTION

The research aims to develop an advance campus security surveillance system leveraging on Arduino microcontroller and CCTV camera technology. The study focused on the design of a scalable and adaptable system capable of monitoring critical areas, detecting intrusion and providing real-time alert in the event of suspicion of potential intrusion. The key objectives include optimizing the integration of Arduino board with surveillance CCTV camera, the implementation of robust intrusion detection algorithm.

Surveillance systems have become indispensable tools in modern security setup. This relevance is promoted by their inherent ability to keep 24/7 watch and create an alarm security breach when a suspicion is identified. The high cost of commercial surveillance systems limits their accessibility, particularly in developing regions, that is why Arduino Uno with its unique capability to interface sensors and with other components to provide robust security is becoming an alternative (Damodaran et al., 2024). In addition to that Arduino uno can be programmed and reprogrammed to suit specific surveillance need.

The rising concern for campus safety necessities the development of advance surveillance systems that act autonomously, leveraging emerging technologies like Arduino microcontroller and cameras offers promising avenues for enhancing campus security. Research by Kim et al. (2021) suggests that implementing an intelligent videos surveillance system based on embedded modules for intruder detection. Additionally, IoT-based smart surveillance system have shown efficiency in high security areas for real-time detecting and alerting (Afreen, 2023). However there remain a gap in tailoring these solutions to cater specifically for security in campus environment.

This study aims to address the gap mention above by developing and optimizing a real-time campus survillance security system. Arduino microcontroller served as a backbone for data processing and control, while camera connected with Aduino Uno microcontroller provide visual data for monitoring critical areas, by integrating motion detection algorithm and real-time communication protocols the system detects intrusion and send alert promptly. This research builds on existing methodologies in embedded systems (Fawzi, 2021) and IoT-based survillance (Ojo, 2022). To tailored a solution suitable for campus security needs.

Related Works

In recent years the integration of Arduino microcontroller and camera systems has gained traction for real time security surveillance, though such implementations have not been optimized for campus use. Researchers have explored different approaches and avenue to improve these systems for enhanced security monitoring particular authors research are reviewed below:

Table 1:Related works by different authors

Author(s)	Year	Title	Purpose	Research Gaps	Performance Metrics
Akhtar, M. U.	2024	Development and evaluation of an Arduino-based data logging system	Develops an Arduino-base data logging system integrated with Microsoft Excell for monitoring purposes	Limited exploration of scalability and broader application	Data accuracy and logging efficiency
Abdulmalek, S.	2022	IoT-Base Healthcare Monitoring System	Reviewed recent studies on IoT-Base Healthcare Monitoring System using Arduino for surveillance	Lack of rea-time processing capabilities in high-density healthcare monitoring system	Accuracy in health monitoring
Bonilla, V.	2023	A systematic review of LaRaWAN sensors application	review of LaRaWAN technology and application with focus on sensors and monitoring	Surveillance application not thoroughly explored	Power efficiency and communication range
Kondaveeti, H. K.	2021	Systematic literature review on prototyping with Arduino	Examine prototyping with Arduino across various domains, including monitoring and surveillance	Limited insights into industrial-level prototyping of surveillance systems	Usability, adaptability, and cost effectiveness
Afreen, H.	2023	IoT-based smart surveillance system for high security	Combines Arduino and GSM for smart surveillance system for high security areas	Lack of case study for real world implementation application	Detection accuracy and system reliability
Witczack, D.	2024	Review of Monitoring and Control Systems Based on IoT	Analyses IoT-based control systems, including applications in environmental and surveillance sectors	Exploration of system failures and performance challenges	Response time, energy consumption
Sánchez, M.	2020	Intelligent Surveillance Systems for Smart Cities	Reviews intelligent surveillance for smart cities, utilizing Arduino-based systems for real-time monitoring	Security challenges in large-scale deployment	Real-time monitoring accuracy

Author(s)	Year	Title	Purpose	Research Gaps	Performance Metrics
Ranjan, P.	2021	Arduino-Based Environment Monitoring Systems	Proposes an environment monitoring system with Arduino for air quality and weather data	Real-time adaptation to extreme environmental conditions	Data collection rate, system durability
Fernandez, J.	2023	Energy-Efficient Surveillance Systems: A Review	Focuses on energy-efficient surveillance using Arduino and IoT	Limited data on long-term power management in complex surveillance environments	Power consumption, battery life
Beniwal, G.	2022	A Systematic Literature Review on IoT Gateways	Investigates IoT gateways, including Arduino-based monitoring systems	Need for improved gateway technologies to support large-scale surveillance systems	Data throughput, network performance

Hardware Components Used

Arduino Uno Microcontroller

The Arduino Uno microcontroller play a pivotal role in the design, development and optimization of the campus surveillance system. It serves as the central processing unit that controls and coordinate and integrate various component such as the Sensor, Servo motor, camera and communication module. Its versatility made it an ideal choice for this project (Akhtar & Iqbal, 2024).

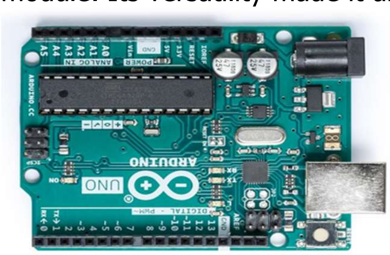

Figure 1: Arduino Uno Microcontroller

PIR motion sensor

Passive Infrared (PIR) motion sensor detects infrared radiation emitted by moving objects particularly humans, when a person is within the sensors field of view, the system recognizes tis as motion and triggers the camera to focus on the area of interest. This ensures the camera only monitors areas of activity and thus optimize usage. PIR sensors typically cover an area up to 10 meters within 100 degrees field of view.

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Figure 2: PIR Motion Sensor

Arduino Camera
The OV7670 camera module is an integral component of the real-time campus surveillance system it provides a low-cost compact solution for capturing images and videos. Enabling real-time monitoring The OV7670 camera captures high quality images and videos at resolution up to 640x480 pixels. This makes it suitable for surveillance application visuals of activities in monitored areas are required
The OV7670 can be interfaced with the Arduino Uno for basic image capturing and processing task. It used in conjunction with external SD card sin Aduino has limited memory. Combining PIR sensor with OV7670 camera ensures that the camera is activated only when motion is detected saving storage space and unnecessary processing.

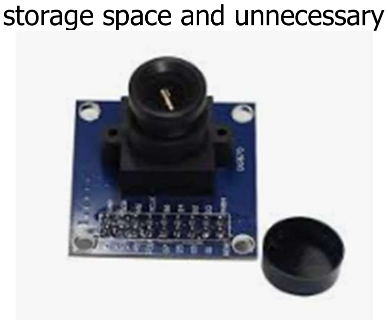

Figure 3: Arduino Camera O7670

Experimental Setup
The system was successfully assembled by connecting the Arduino Uno with Wi-Fi module, camera. Motion sensor and SD card module. Arduino Uno is programmed using Arduino IDE 2.3.4, it acts as the Central Processing Unit, which receives inputs from the PIR sensor that continuously monitors the environment for motion. Once motion is detected the sensor send signal to Arduino which triggers the system to activate the CCTV camera for real-time surveillance and recording. The camera is mounted on servo motor which tilt based on input from the programing.
The TX pins of the of the Arduino is connected to the Arduino while the RX pin from the Wi-Fi module is connected to the Arduino. The Wi-Fi module extend the system functionality by enabling remote monitoring and transmission of live footage from the CCTV camera streamed to the control room or smartphone enabling the security personnel to monitor the CCTV camera feed in real-time. Additionally, Machine algorithm such as k-means clustering was employed for anomaly detection, enabling the system to identify suspicious activity and send real-time alerts to designated devices.

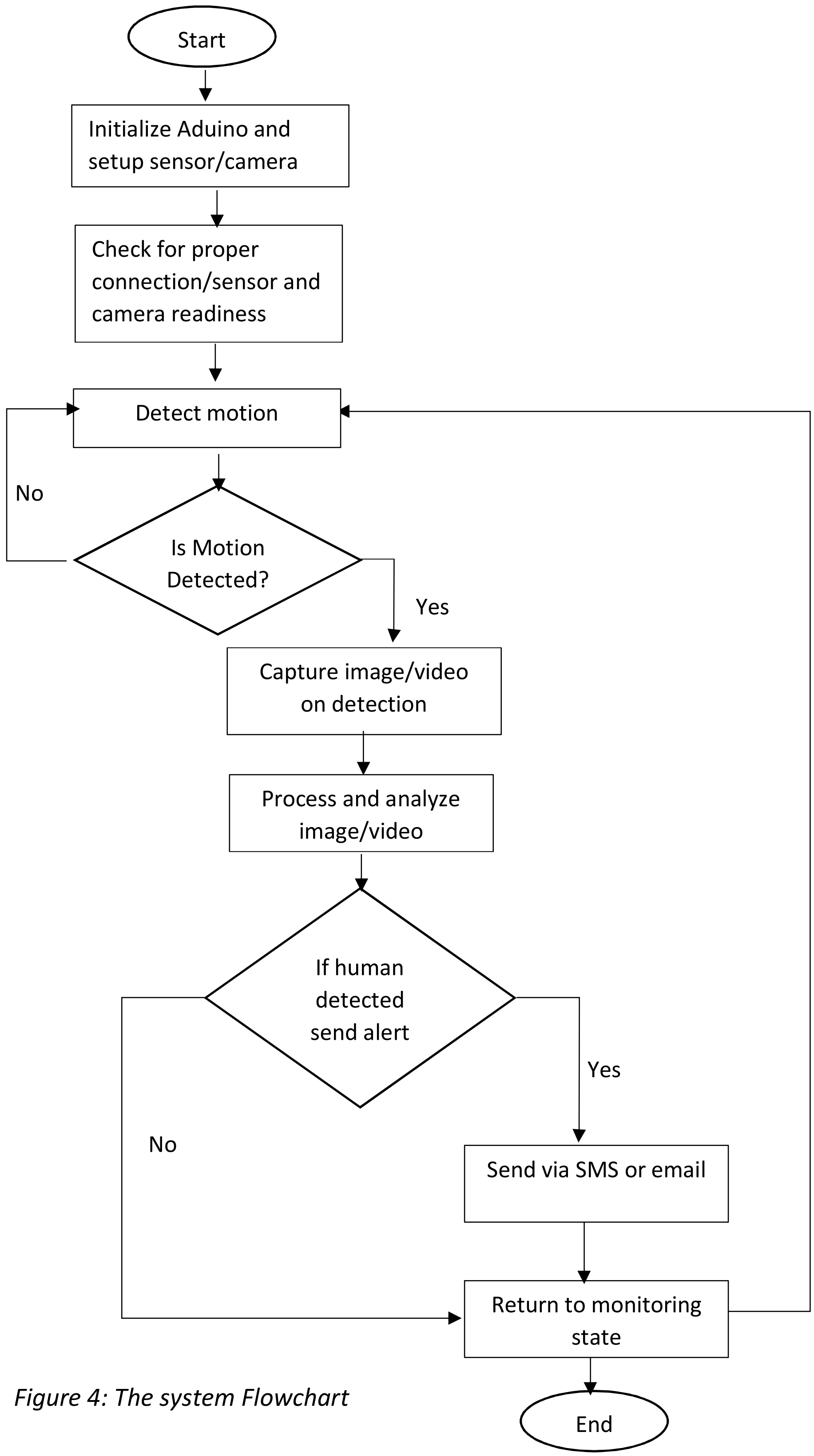

Figure 4: The system Flowchart

RESULT AND DISCUSSION

Table 2: System Test Data set

Test ID	True Positive (TP)	False Positive (FP)	False Negative (FN)	True Negative (TN)
Test 1	25	1	2	70
Test 2	28	2	1	69
Test 3	27	1	3	68
Test 4	26	2	4	71
Test 5	30	1	2	61
Average	27.2	1.4	2.4	69.2

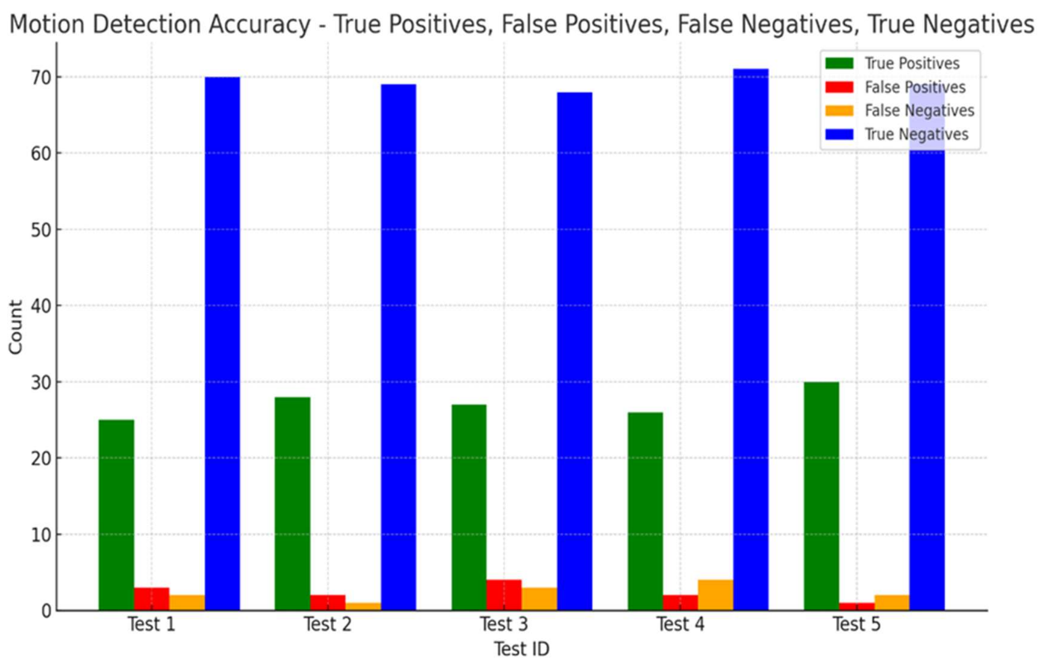

Figure 5: Graphical Representation of test dataset

The average of 27.2 for True Positive (TP) suggests that the system reliably detects motion and perform consistently across test. The low average of 1.4 showed that the system rarely falsely detect motion when there is none. The average of 2.4 for False Negative (FN)is little bit higher than necessary this may be due sensor sensitivity to environmental factors, but the average is not big enough to invalidate the system reliability. True Negative (TN) has an average of 69.2 indicate that the system is reliable in detecting when there is no motion thus contributing to the overall reliability of the system.

To analyze the overall performance of the system we will use the above information to compute the accuracy, precision and recall as define below:

Accuracy measures the overall correctness of the system capability to detect motion

$$\boldsymbol{Accuracy} = \frac{(TP+TN)}{(TP+FP+FN+TN)} * 100 \text{ ------}$$ *Equation 1: for computation accuracy*

Precision measures the proportion of true positives in all detected motion

$$\boldsymbol{Precision} = \frac{TP}{(\mathrm{TP}+\mathrm{FP})} * 100 \text{ -------------------}$$ Equation 2: for computation of precision

Reall measures the proportion of actual motion that were correctly detected

$$\boldsymbol{Recall} = \frac{TP}{(\mathrm{TP}+\mathrm{FN})} * 100 \text{ ------------------------}$$ Equation 3: for computation of recall

Table 3: System performance metrics

Test ID	Accuracy %	Precision %	Recall %
Test 1	95.00	89.29	92.59
Test 2	96.25	93.33	96.55
Test 3	94.75	87.10	90.00
Test 4	96.25	92.86	86.67
Test 5	98.75	96.77	93.75

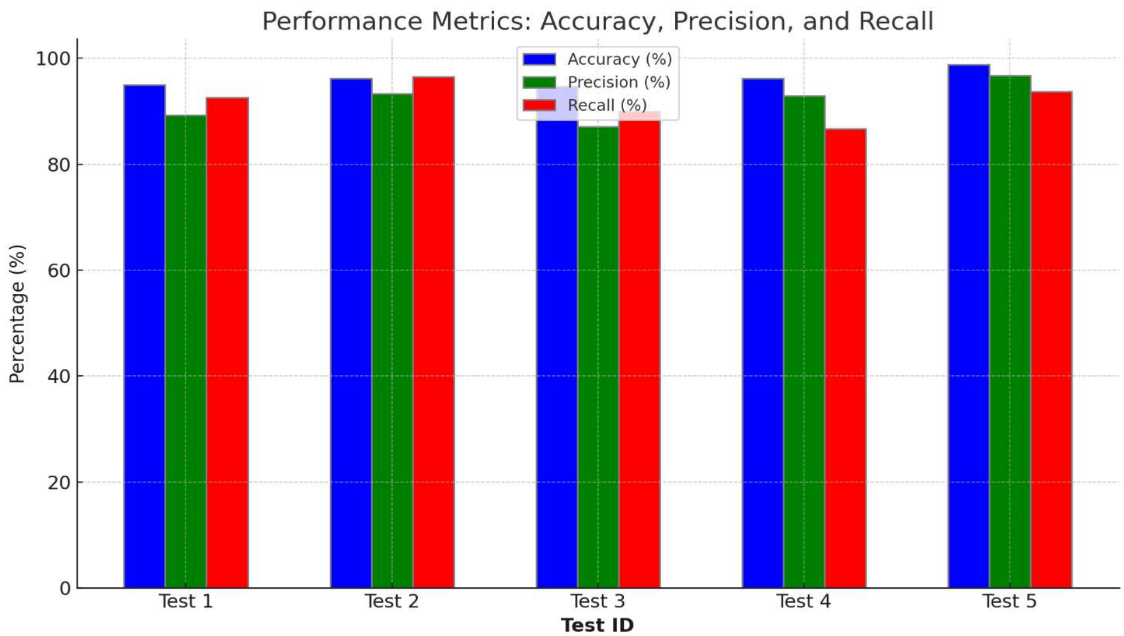

Figure 6: Graphical representation of system performance metrics

The system's accuracy is consistently high across tests ranging from 94.75% to 98.75%. Precision shows the system is generally good at minimizing false positive, though with some variability. Recall values suggest that the system effectively detect most motion event.

CONCLUSION

The development and optimization of a real-time campus security survillance system using Arduino and CCTV camera offer a significant enhancement in campus safety. This system integrates cost-effective hardware such as Arduino, PIR sensor and camera with smart algorithms to monitor and respond to security threats effectively. By leveraging real-time data processing, the system can detect and alert authorities to potential security breaches, ensuring timely intervention. The optimization of this system for campus environment highlights its scalability adaptability to different security needs, making it a vital tool for modern security enhancement and management.

REFERENCES

Abdulmalek, S. (2022). IoT-Based Healthcare-Monitoring System Towards. *PMC*. https://pmc.ncbi.nlm.nih.gov/articles/PMC9601552/

Afreen, H. (2023). IoT-Based Smart Surveillance System for High-Security. *MDPI*. https://www.mdpi.com/2076-3417/13/15/8936

Akhtar, M. U., & Iqbal, M. T. (2024). Development and Evaluation of an Arduino-Based Data Logging System Integrated with Microsoft Excel for Monitoring On-Grid Photovoltaic Systems. *European Journal of Electrical Engineering and Computer Science*, *8*(3), 29–37. https://doi.org/10.24018/ejece.2024.8.3.622

Beniwal, G. (2022). A Systematic Literature Review on IoT Gateways. *ScienceDirect*. https://www.sciencedirect.com/science/article/pii/S1319157821003219

Bonilla, V. (2023). A Systematic Literature Review of LoRaWAN: Sensors and Applications. *MDPI*. https://www.mdpi.com/1424-8220/23/20/8440

Fernandez, J. (2023). Energy-Efficient Surveillance Systems: A Review. *ResearchGate*.

Kondaveeti, H. K., & Kumaravelu, A. (2021). A Systematic Literature Review on Prototyping with Arduino. *ResearchGate*. https://www.researchgate.net/publication/354362639

Kim, J. S., Kim, M., & Pan, S. B. (2021). A study on implementation of real-time intelligent video surveillance system based on embedded module. *Eurasip Journal on Image and Video Processing*, *2021*(1). https://doi.org/10.1186/s13640-021-00576-0

Ojo, O. (2022). An Internet-of-Things based Real-time Monitoring System for Classroom Seat Allocation. *Journal of Nigerian Society of Physical Sciences*, 4(2), 78-86.

Ranjan, P. (2021). Arduino-Based Environment Monitoring Systems. *Academia*. https://www.academia.edu/108157720

Sánchez, M. (2020). Intelligent Surveillance Systems for Smart Cities. *ResearchGate*. https://www.researchgate.net/publication/354362639

Witczak, D. (2024). Review of Monitoring and Control Systems Based on IoT. *MDPI*. https://www.mdpi.com