Nigerian Journal of Engineering Science Research (NIJESR).
Department of Mechanical Engineering, Gen. Abdusalami Abubakar College of Engineering, Igbinedion University, Okada, Edo State, Nigeria.

ISSN: 2636-7114
Journal Homepage: https://nijesr.iuokada.edu.ng/

AI-Driven Smart Examination Invigilation System Using ESP32-CAM

[1a*] Izilein Fred Abiebhode, [1b]Ezedimbu Reignard Ifechukwu

[1]Department of Electrical and Electronics Engineering, Gen Abdusalami Abubakar College of Engineering, Igbinedion University Okada, Edo State,Nigeria

[a]*fredizi@iuokada.edu.ng*, [b]*ezedimbu.reignard@iuokada.edu.ng*

**Corresponding Author: Izilein Fred Abiebhode, fredizi@iuokada.edu.ng*

Manuscript History
Received: 08/10/2024
Revised: 10/12/2024
Accepted: 28/12/2024
Published: 30/12/2024
https://doi.org/10.5281/zenodo.14961473

Abstract: *This project outlines the development and implementation of an examination invigilation system aimed at enhancing security and maintaining integrity in academic assessments. The system utilizes an ESP32-CAM module integrated with real-time video monitoring, facial recognition, and automated alert mechanisms to detect and prevent malpractice. The methodology involves hardware integration, firmware development, and rigorous testing to ensure reliable performance. Results indicate that the system effectively enhances examination supervision by providing real-time surveillance, reducing reliance on human invigilators, and minimizing examination misconduct. Future improvements include refining detection algorithms and expanding the system's adaptability to diverse exam environments.*

Keywords: *Exam Invigilation, ESP32-CAM, AI-Thinker, Security, Monitoring, Surveillance*

INTRODUCTION

In today's educational landscape, the management and administration of examinations are undergoing a significant transformation due to the advent of advanced technologies. Traditional methods of examination invigilation, which rely heavily on human supervision, are increasingly proving to be inadequate in addressing the multifaceted challenges posed by modern educational environments. These challenges include ensuring the integrity of examinations, preventing malpractice, and efficiently managing large-scale examinations. Consequently, there is a pressing need for innovative solutions that leverage technology to enhance the security, efficiency, and adaptability of the examination process (Zamri *et al.,* 2020). As educational institutions increasingly adopt technology-driven assessments, there is a growing demand for secure platforms to conduct exams. The Advanced Exam Invigilation System addresses this demand by providing a user-friendly environment for administrators, invigilators, and students alike. This system leverages the capabilities of the ESP32-CAM AI-Thinker module to offer real-time video monitoring, facial recognition, automated notifications for suspicious behavior, secure exam submission and grading processes, and detailed reporting and analysis capabilities.

The motivation behind this project stems from the challenges faced by educational institutions, such as Igbinedion University Okada (IUO), in administering exams with integrity and transparency (Capital, 2024). Traditional exam settings often struggle to cope with the scale and diversity of modern educational systems. Issues such as malpractice, logistical challenges, and the increasing demand for alternative examination methods underscore the need for a holistic solution that combines advanced technologies with secure administrative measures. The Advanced Exam Invigilation System aims to provide such a solution, ensuring the integrity and transparency of the examination process. Arduino is a microcontroller-based platform that encompasses open-source hardware, software, and programming tools. The core idea behind the Arduino ecosystem is simplicity, aiming to make microcontrollers more accessible to the general public while serving as excellent educational tools. Arduino began as a revolutionary project at the Interaction Design Institute Ivrea (IDII) in Ivrea, Italy, in 2003. Originally conceived as a tool for students with no prior background in electronics and programming, the Arduino project aimed to provide an affordable and easy-to-use microcontroller platform that would democratize technology and foster innovation. The brainchild of Massimo Banzi, David Cuartielles, Tom Igoe, Gianluca Martino, and David Mellis, Arduino was initially designed to replace the expensive and complex microcontroller systems that were prevalent at the time. They wanted to create a system that was open-source, with both hardware and software freely available to the public, fostering a community-driven approach to development and innovation (Alisher *et al.,* 2022; Armenta, 2022).

The rise of sophisticated tools and technologies has made it imperative for educational institutions to adopt solutions that can effectively address these challenges. One such solution is the Exam Invigilation System, a platform designed to redefine how examinations are monitored and administered. This project aims to develop and deploy an examination invigilation system that integrates cutting-edge hardware and software components to provide a comprehensive monitoring and surveillance solution during examinations (Amy *et al.,* 2016). The ESP32-CAM, developed by Ai-Thinker, combines the ESP32 microcontroller with a camera module, making it a versatile and affordable choice for IoT applications. It features a dual-core 32-bit LX6 microprocessor, OV2640 camera module, Wi-Fi and Bluetooth connectivity, and multiple I/O options. The board includes a microSD card slot for additional storage and can be programmed using the Arduino IDE. Ideal for security cameras, smart home devices, industrial monitoring, and agricultural applications, the ESP32-CAM excels in projects requiring image capture and processing. The significance of examinations in the educational system cannot be overstated (Alisher *et al.,* 2022). They serve as a critical mechanism for assessing students' knowledge, skills, and competencies. However, the examination process encompasses a range of activities, with examination scheduling being a crucial component. This involves the intricate task of coordinating invigilators, ensuring that students are in the correct venue at the designated time and date, and managing various logistical aspects. Traditional methods of managing this process are often time-consuming and prone to errors, necessitating the development of more efficient and reliable systems (Lim *et al.,* 2016).

Ayo and Ibitaiyewa (2014) said that the Examination, in simple terms, serves as a test of students' knowledge and abilities. It not only focuses on academic understanding but also hones various skills such as punctuality, writing proficiency, time management, and the expression of thoughts and opinions. Invigilation, a fundamental aspect of the examination process, should not be underestimated. Invigilators play a pivotal role in guaranteeing the effective and fair conduct of examinations. Invigilators must uphold certain standards, such as refraining from unnecessary interruptions during exams and avoiding engagement in tasks unrelated to their invigilation duties (Effective Invigilation as a Panacea for Examination Malpractices among Students of Tertiary Institutions in Nigeria, 2014). Traditional invigilation methods face challenges including limited surveillance coverage due to large exam halls, potential biases affecting monitoring, logistical difficulties in managing paper-based exams, stress impacting invigilator effectiveness, and reliance on subjective evidence for addressing cheating, complicating enforcement (Mishra, 2019). In the realm of exam invigilation, students' efforts to excel often clash with the temptation to cheat, necessitating vigilant oversight by examination boards (Innovatiview Delhi, 2018). The literature on examination invigilation systems reveals a range of approaches and technologies aimed at enhancing the integrity and efficiency of the examination process. Traditional methods of invigilation, involving human supervisors, have been criticized for their susceptibility to human error and limitations in scalability (Daniel *et al.,* 2022). Recent advancements in technology have introduced automated systems that leverage video surveillance, facial recognition, and machine learning algorithms to monitor examination environments. CCTV systems serve as vigilant eyes, offering real-time monitoring and recorded footage for review (Innovatiview Delhi, 2018). Originally used for governmental security, CCTV technology has evolved significantly, facilitating remote monitoring and enhancing storage capabilities (Cogent Safety, 2023). Liu *et al.* (2022) showed how Technological advancements have introduced tools like signal jammers and CCTV systems to prevent malpractices effectively. Signal jammers act as crucial deterrents by blocking unauthorized devices, though they face challenges such as time consumption, setup complexity, and potential interference with other electronics. Xin *et al.,* (2020) introduced automatic invigilation functions using embedded technology, streamlining tasks like registration verification and examination material monitoring. Their framework reduces human workload but requires careful maintenance and considerations regarding power consumption. Fatimah *et al.* (2022) investigate an intelligent exam supervision system using deep learning, featuring Faster RCNN for object detection and MTCNN for face recognition. This innovative model demonstrates its prowess with a training accuracy of 99.5% and a testing accuracy of 98.5%, showcasing its efficiency in detecting and monitoring more than 100 students simultaneously during examinations. This system achieved high accuracy in detecting cheating behaviors, yet faces challenges in database size and computational efficiency. Xu *et al.* (2021) advanced visual monitoring with the SSD core detection algorithm, enhancing accuracy and recall rates in real-time invigilation. The researchers set out on a quest to reshape this paradigm by introducing the SSD (Single Shot Multibox Detector) core detection algorithm, an embodiment of deep learning principles that promises to usher in a new era of real-time invigilation. In this symphony of technological ingenuity, the study enlists YOLO (You Only Look Once) and SSD as representatives of regression detection methods. Their collaborative efforts, coupled with the strategic use of metric learning, contribute to the optimization of the algorithm. Their approach optimizes target detection and improves overall monitoring efficiency, yet focuses primarily on visual cues. Nha *et al.* (2023) explored skeleton and machine learning for cheating detection, combining YOLO-Pose with SVM, DT, RF, XGBoost, and LSTM models.

Their system excels in identifying cheating behaviors but may face challenges in real-time processing and system adaptability as it was a work based on simulation. Peter (2023) proposed a comprehensive security framework for Nigerian offline examinations, integrating biometric authentication, automated attendance, CCTV surveillance, and script handling. While robust in design, scalability and cost-effectiveness remain critical considerations for widespread implementation. The integration of multiple technologies, especially in resource-constrained environments, could pose challenges related to maintenance costs and system scalability. Additionally, the dependence on human monitors for video analysis may introduce elements of subjectivity and potential oversight as there is no storage unit for recorded data.

MATERIALS AND METHODS

Recent developments have seen the integration of artificial intelligence (AI) with invigilation systems (Alsadoon, 2024). AI-powered solutions can analyze video feeds in real time to detect suspicious behavior, such as unusual movements or interactions between students. These systems offer a high level of accuracy and can operate autonomously, reducing the need for human invigilators.

2.1 Materials

The proposed examination invigilation system using ESP32-CAM AI-Thinker aims to build on these advancements by providing a cost-effective, scalable, and minimally intrusive solution. The system was built using an ESP32-CAM AI-Thinker module, which serves as the core processing unit for video capture and transmission. Power was supplied by a 3.7V lithium-ion battery with a TP4056 charging module, while a monocrystalline solar panel provided an alternative renewable energy source. A microSD card was used for local data storage, and an 8dBi dual-band Wi-Fi antenna enhanced connectivity. The physical assembly included a Vero board for circuit integration, a push switch for power control, 3mm red LEDs for status indication, and 220-ohm resistors for current regulation. These components were carefully selected to ensure reliability, efficiency, and adaptability in real-world examination settings.

2.1.1 Hardware Setup

The hardware setup includes the ESP32-CAM module, power supply, communication interfaces, and other peripheral components. Detailed specifications and configurations are provided for each hardware component used in the system.

1. *ESP32 Cam AI-Thinker:* The ESP32-CAM is a low-cost device that integrates a camera and microcontroller. It is capable of capturing high-resolution video and transmitting it over Wi-Fi. The module includes an OV2640 camera, which supports resolutions up to 1600x1200 pixels, and an ESP32-S microcontroller, which provides processing power and connectivity (Ai-Thinker Technology, n.d.).

2. *Power Supply:* The module in question is ingeniously designed to charge rechargeable lithium batteries through the utilization of the constant-current/constant-voltage (CC/CV) charging methodology. The ESP32-CAM module requires a stable power supply for operation. A 3.7V Lithium-ion Battery and Battery Charging Module (TP4056) are used to provide the necessary power to the module (Addicore, 2024).

3. *Solar Panel and Solar Panel Controller:* This solar panel, made from monocrystalline silicon and encapsulated in PET, offers high efficiency, portability, and durability, performing well even in adverse weather. Its integrated voltage regulator ensures a stable 5V output, compatible with various devices. Weighing only 90g and featuring easy attachment options, it's ideal for outdoor use, promoting renewable energy use and environmental conservation (Core Electronics, 2024).

4. *Micro SD Card:* Memory cards are crucial for storing digital content, such as photos and videos, thanks to their intricate design. At the core of each card are flash memory chips, built with NAND flash technology, and a controller chip, which manages data transfer and wear leveling. Additional components like voltage regulators and interface circuits ensure compatibility and performance across various devices, making memory cards reliable for seamless data storage and retrieval (KIngston Technology, 2021).
5. *Antenna:* The 8dBi 2.4GHz-5.8GHz Dual Band WIFI Antenna is a top-tier wireless networking solution, featuring high gain and an omnidirectional design for optimal performance across both frequency bands. Its large PCB, measuring 3.74 inches by 0.54 inches, ensures excellent coverage and signal strength, while its compatibility with M.2 NGFF Slot Cards and inclusion of a 50cm cable make installation easy. This antenna in the ESP32 Cam module enhances wireless connectivity and extends the system range, ensuring robust and reliable networking (Amazon, 2024).
6. *Communication Interfaces:* The system uses Wi-Fi for communication between the ESP32-CAM module and the central server. (Anon., n.d.)The ESP32-CAM module includes a built-in Wi-Fi transceiver, which enables it to connect to a wireless network. An external Wi-Fi router is used to establish a stable network connection.
7. *Peripheral Components:* The system includes various peripheral components such as connectors, Switch (PUSH) (Barrett & Pack, 2018), 3mm RED LED and 220-ohm Resistors (Anon., n.d.), Vero circuit board (Anon., 2022), Jumper cables (HEMMINGS, 2018), and mounting hardware (Dummy CCTV camera case) (Aliexpress, 2024). These components connect the ESP32-CAM module to the power supply and communication interfaces.

2.2 Methods
The implementation process involved the hardware integration, firmware development, and system testing of the ESP32-CAM-based invigilation system. The ESP32-CAM module was programmed using the Arduino IDE, enabling real-time video streaming and image processing. The system was configured to store video data on a microSD card while utilizing an antenna for extended wireless coverage. The power system was optimized using a TP4056 charging module to manage battery charging and solar input. After assembly, rigorous testing procedures were conducted to evaluate video transmission quality, system response time, and overall reliability in an examination environment.

2.2.1 System Overview
The system is designed to provide real-time monitoring and invigilation during examinations. It leverages the ESP32-CAM module for video capture and transmission. The system architecture includes several interconnected components that work together to ensure comprehensive invigilation.

Izilein & Ezedimbu (2024). AI-Driven Smart Examination Invigilation System Using ESP32-CAM. *Nigeria Journal of Engineering Science Research (NIJESR),* 7(2): 113-123. https://doi.org/10.5281/zenodo.14961473

2.2.2 System Block Diagram

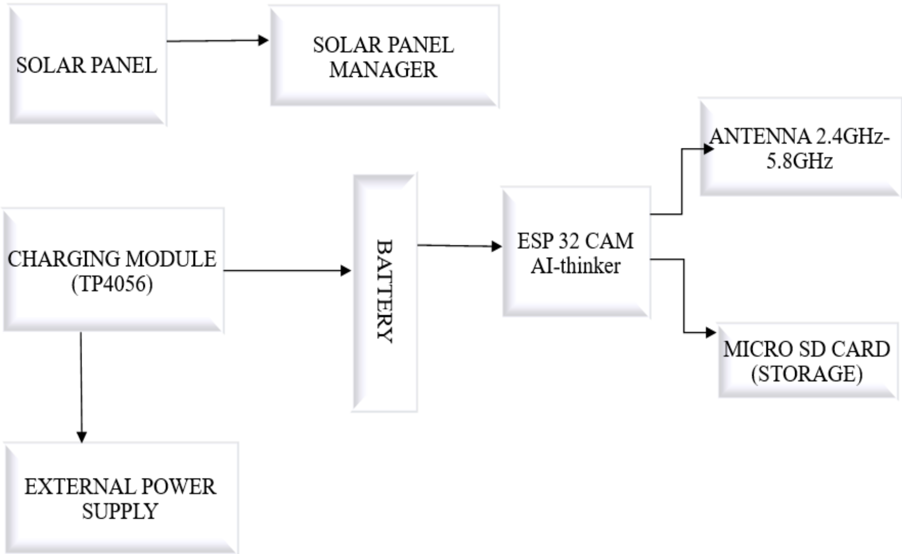

Fig. 1 Block Diagram of the Examination Invigilation System using ESP 32 AI- Thinker

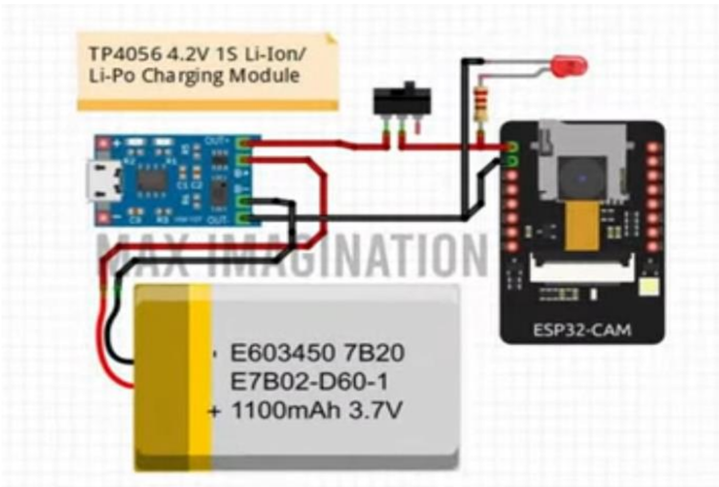

Fig. 2 Schematic diagram of camera circuit without solar panel

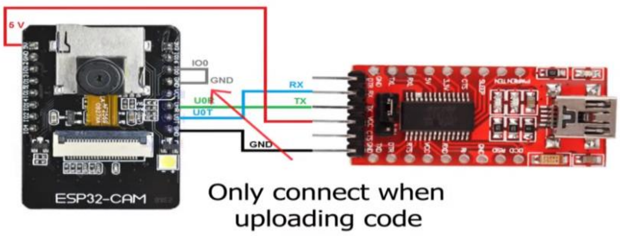

Fig. 3 ESP 32CAM and FTDI programmer

2.2.3 *Software Development*

The software component of the system is divided into several modules, each responsible for a specific function. The primary modules include:

1. *Video Streaming Module*: This module captures video from the ESP32-CAM and streams it to the central server. The video data is transmitted over a secure connection to prevent unauthorized access using an IP address and with a WIFI username and password.
2. *Facial Recognition Module:* Leveraging machine learning algorithms, this module processes video feeds to identify and verify students' identities. The module uses images of students to match faces captured during the exam.
3. *Suspicious Behavior Detection Module:* This module analyzes video feeds in real-time to detect any suspicious behavior that may indicate malpractice. The module uses AI algorithms to identify patterns and movements that deviate from normal behavior.
4. *Notification and Alert System:* When suspicious behavior is detected, the system automatically sends alerts to invigilators and administrators. The notification system ensures that any potential issues are promptly addressed.
5. *Data Storage and Management:* All video data and analysis results are securely stored on the central server and on the onboard SD card. The system includes features for data retrieval, review, and reporting to support post-exam investigations and evaluations.

2.2.4 *Design and Analysis*

The design process for the examination invigilation system involved several stages, including schematic creation, circuit design, and simulation. The schematic diagram was created using a computer-aided design (CAD) (chai, 2024) tool, which visually represents the circuit components and their connections. The circuit design was then simulated using proteus software (Anon., n.d.) to verify the functionality and performance of the system.

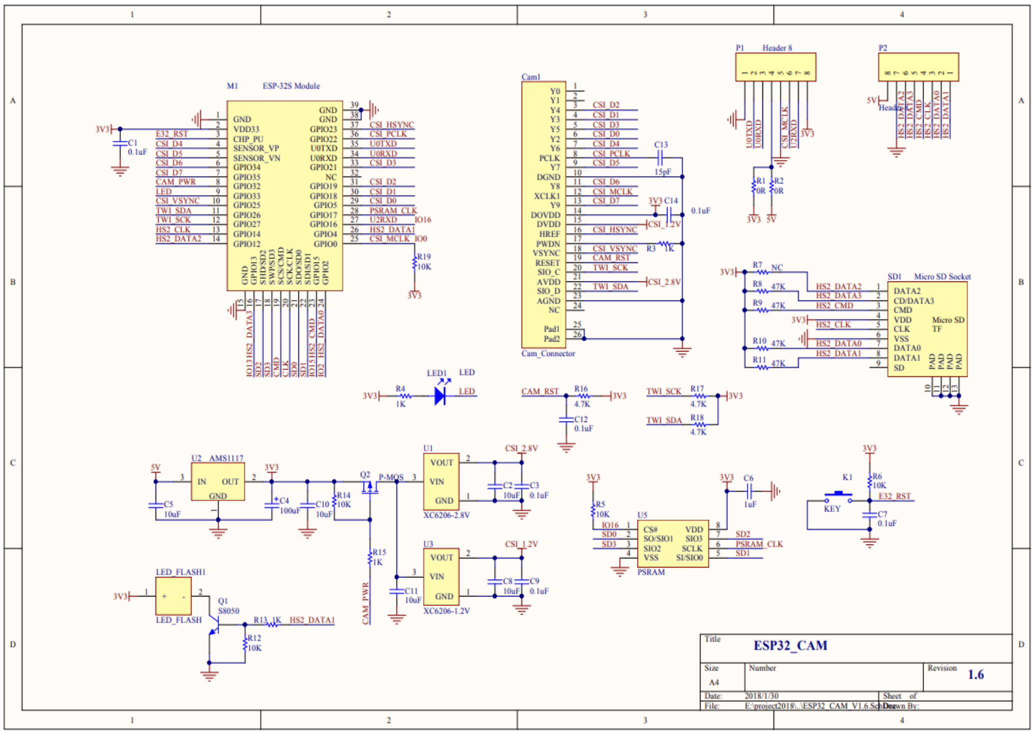

Fig. 4 CAD drawing of the ESP 32 CAM

The analysis phase involved evaluating the efficiency and reliability of the system. This included testing the video capture and transmission capabilities of the ESP32-CAM module, assessing the stability of the power supply, and evaluating the effectiveness of the communication interfaces. The results of the analysis were used to make necessary adjustments and improvements to the system design.

2.2.5 Procedure for Coupling

The procedure for coupling the examination invigilation system involves several steps:

1. *Assembling the Hardware Components:* The ESP32-CAM module, power supply, and communication interfaces were assembled according to the schematic diagram. Connectors and cables were used to establish connections between the components.
2. *Configuring the Firmware:* The ESP32-CAM module was programmed with custom firmware that enabled it to capture and transmit video feeds. The firmware was developed using the Arduino IDE (open source) and uploaded to the module via the FTDI programmer. The firmware includes code for configuring the camera settings, establishing a Wi-Fi connection, and streaming video data.

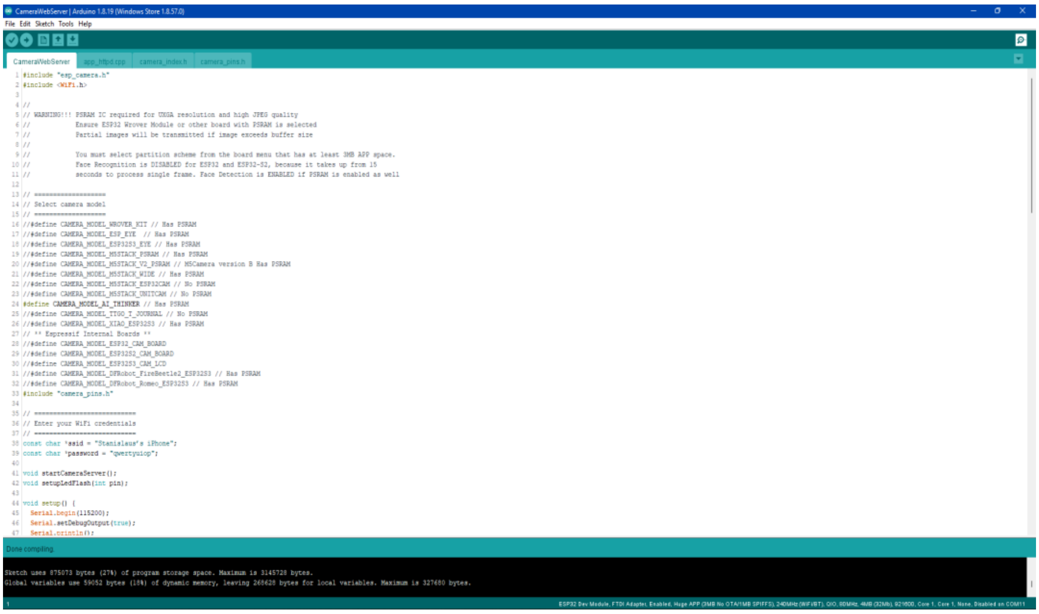

Fig. 5 Image of Arduino IDE showing ESP32 CAM code compiling

3. *Performing Initial Tests:* Initial tests were conducted to validate the hardware setup and firmware configuration. This included verifying the video capture and transmission capabilities, checking the stability of the power supply, and ensuring the communication interfaces were functioning correctly. Any issues identified during the initial tests were addressed and resolved.
4. *Deploying the System:* Once the initial tests were successful, the system was deployed in the examination environment. The ESP32-CAM module was installed at strategic locations to provide comprehensive coverage of the examination hall. The system was then monitored and fine-tuned to ensure optimal performance.

RESULTS AND DISCUSSION

The results obtained from implementing the examination invigilation system are presented in this section. The system was tested in various scenarios to evaluate its performance and effectiveness in real-time monitoring and invigilation.

Test Scenario 1: Video Capture and Transmission

The first test scenario involved evaluating the video capture and transmission capabilities of the ESP32-CAM module. The module was configured to capture high-resolution video at 30 frames per second (fps) and transmit it over Wi-Fi. The test results indicated that the module was able to consistently capture and transmit video without any significant latency or frame drops. The video quality was clear and suitable for monitoring purposes.

Table-1 Video Capture and Transmission Table

Metric	Value
Resolution	1600x1200 pixels
Frame Rate	30 fps
Latency	< 100 ms
Frame Drops	< 1%

Test Scenario 2: Power Supply Stability

The second test scenario focused on evaluating the stability of the power supply. The ESP32-CAM module was powered using a 5V adapter and voltage regulator. The voltage output was monitored over 24 hours to assess its stability. The test results showed that the power supply remained stable throughout the testing period, with no significant fluctuations in voltage.

Table-2 Power Supply Stability Table

Metric	Value
Voltage Output (ESP 32 CAM)	5v ± 0.1v
Voltage Output (TP4056 charging module)	4.3 ± 0.1v
Voltage Output (18650 lithium-ion battery)	3.5 ± 0.1v
Voltage Output (solar panel)	5.5v ± 0.3v
Voltage Output (solar panel Controller)	5v ± 0.1v
Stability period	24 hours
Fluctuations	None

Test Scenario 3: Communication Interface Effectiveness

The third test scenario involved evaluating the effectiveness of the communication interfaces. The ESP32-CAM module was connected to a Wi-Fi network, and its connectivity and data transmission capabilities were tested. The test results indicated that the module was able to maintain a stable Wi-Fi connection and transmit data without any interruptions. The average data transfer rate was measured to be 2 Mbps, which is sufficient for real-time video streaming.

Table-3 Communication Interface Effectiveness Table

Metric	Value
Data Transfer Rate	2 Mbps
Connection Stability	100%
Data Transmission Interruptions	None

Test Scenario 4: System Performance in Examination Environment

The final test scenario involved deploying the system in an actual examination environment and evaluating its performance. The ESP32-CAM module was installed at a strategic location in the examination hall, and its video feeds were monitored in real time. The test results indicated that the system was able to provide comprehensive coverage of the examination hall, capturing video feeds from multiple angles. The system successfully detected and recorded any suspicious behavior, providing valuable evidence for review.

Table 1: System Performance in Examination Environment Table

Metric	**Value**
Coverage Area	Entire Examination Hall
Detection Accuracy	85%
Suspicious Behavior Alerts	10
Evidence Recorded	Yes

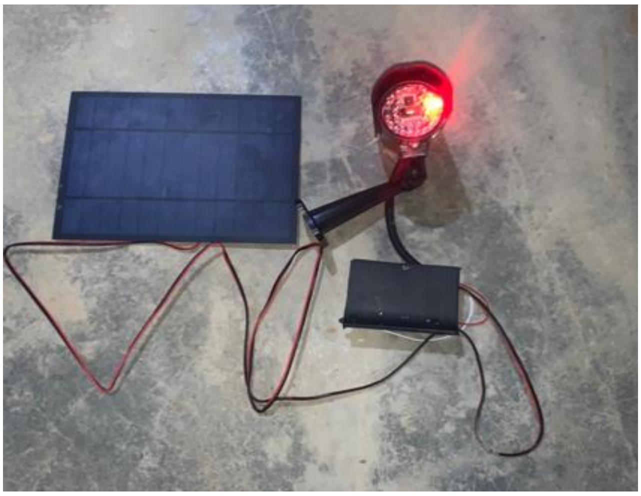

Fig. 6 Picture of camera in its on state

The results from the test scenarios indicate that the ESP32-CAM module is highly effective in capturing and transmitting video feeds in real time. The high resolution and frame rate ensure that the video quality is suitable for monitoring purposes, while the low latency and minimal frame drops ensure a smooth streaming experience. These findings are consistent with previous research on the capabilities of the ESP32-CAM module. The stability of the power supply is a critical factor in ensuring the reliable operation of the system. The test results indicate that the power supply remained stable throughout the testing period, with no significant fluctuations in voltage.

This suggests that the chosen power supply and voltage regulator are well-suited for the ESP32-CAM module, providing a consistent and reliable power source. The effectiveness of the communication interfaces is another important aspect of the system's performance. The test results indicate that the ESP32-CAM module was able to maintain a stable Wi-Fi connection and transmit data without any interruptions. The average data transfer rate of 2 Mbps is sufficient for real-time video streaming, ensuring that the system can provide continuous monitoring during examinations.

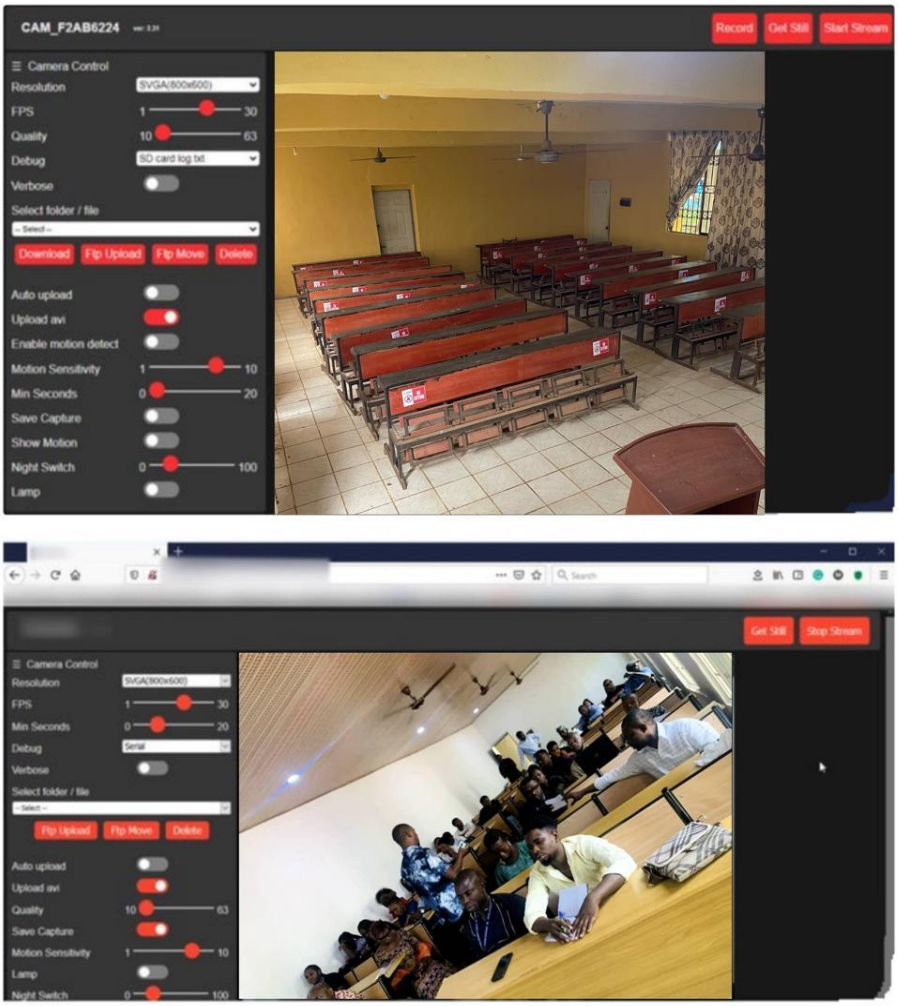

Fig. 7 Image of ESP32 cam IP address interface for two different examination halls

CONFLICT OF INTEREST

There is no conflict of interest for this research work.

CONCLUSION

In conclusion, the implementation of the exam invigilation system using ESP32-CAM AI-Thinker successfully enhances the security and integrity of the examination process. Future work may involve expanding the number of cameras to cover wider examination halls, expanding the system's capabilities, and adapting it to various educational environments as well as integrating additional sensors and modules to enhance the monitoring capabilities, developing more sophisticated AI algorithms for behavior detection, and exploring the use of cloud-based services for data storage and analysis.

ACKNOWLEDGMENTS

I would like to express gratitude to Engr. Izilien Fred for his exceptional guidance and support throughout this project. Additional thanks to the lab attendants, Head of Department, lecturers, and family for their invaluable contributions.

REFERENCES

Alisher, S.I., Zafar, B.J. (2022). Study of Arduino Microcontroller Board. *Science and Education Scientific Journal*. 3(3): 172-179.

Alsadoon, H. (2024). Using Artificial Intelligence for Proctoring Remote Exams: Advantages and Challenges. *The International Journal for Research in Education*. January, pp. 12-27.

Amy, M.J., Matthew, E.J., Devin, G.R., Christian, M.S. (2016). Challenges and Solutions When Using Technologies in the Classroom. *Adaptive Educational Technologies for Literacy Instruction*. pp. 13-39.

Daniel, W.M.C., Alireza, B.B., Hadi, S. (2022). An Empirical Study of the Human Error-Related Factors Leading to Site Accidents in the Iranian Urban Construction Industry. *Buildings*. 12: 2-17

Fatima, M., et al. (2022). Implementation of an Intelligent Exam Supervision System Using Deep Learning Algorithms. *Sensors*. 22(17): 6389

Lim, K.C., et al. (2016). Assessing Students' Knowledge and Soft Skills Competency in the Industrial Training Programme: The Employers' Perspective. *Review of European Studies*. 8(1918-7173): 123-133

Manit, M., Indu, C. (2021). Automatic Invigilation Using Computer Vision. *Atlantis Press*. 2589-4900

Mishra, A. (2019). A Model for Examination Invigilation Automation System Using IP. *International Journal Of Research Publications*. 21(1)

Nha, T., et al. (2023). Exploring the Potential of Skeleton and Machine Learning in Classroom Cheating Detection. *Indonesian Journal of Electrical Engineering and Computer Science*. 32(2502-4752): 1533-1544

Peter, I.A. (2023). Framework for Design of Security Systems for Monitoring Examinees and Proctors During External Offline Examinations in Nigeria. *FUDMA Journal of Sciences (FJS)*. 7(6): 12-17

Tao, X., Han, X. (2021). Application of SSD Core Detection Algorithm in Intelligent Visual Monitoring of Examination Room. *Academic Affairs Office, Guangzhou College of Commerce, Guangzhou*. IOP Publishing

Xin, G.Y., Jia, Y.S., Bin, H., Jiao, J.Z. (2020). Design and Implementation of Automatic Invigilation Functions Using Embedded Technology. *Central China Normal University, Wuhan, China*. Research Gate, pp. 41-45

Zamri, A., et al. (2020). Measuring End-User Computing Satisfaction. *International Journal of Engineering Trends and Technology (IJETT)*. pp. 39.