UNIVERSITY of RWANDA

College of Science and Technology

Website: www.aceiot.ur.ac.rw
Mail: aceiot@ur.ac.rw

AFRICAN CENTER OF EXCELLENCE IN INTERNET OF THINGS

Research Thesis Title: Real-Time Security System with Object Detection: Recognizing Objects in Real-Time Using Cameras and Sensors in an IoT System

A dissertation submitted in partial fulfilment of the requirements for the award of masters of science degree in internet of things: Embedded computing system

Submitted by:

Name: **BYIRINGIRO Pacifique** (**Reg No: 221031403**)

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DECLARATION

I **BYIRINGIRO Pacifique**, Master student from African Center of Excellence in internet of things, at University of Rwanda. I declare that this research thesis with title: **Real-Time Security System with Object Detection: Recognizing Objects in Real-Time Using Cameras and Sensors in an IoT System** is my own original work and it has never been presented before anywhere in the world.

Names: **BYIRINGIRO Pacifique**

Ref: **221031403**

Signed:

Date: 08/10/2024

BONAFIDE CERTIFICATE

This is to certify that this submitted Research Thesis work report is a record of the original work done by **BYIRINGIRO Pacifique** (**Ref. Nu: 221031403**), MSc. IoT-ECS Student at the University of Rwanda / College of Science and Technology / African Center of Excellence in Internet of Things, the Academic year 2021/2023.

This work has been submitted under the supervision of **Dr KAYALVIZHI Jayavel** and **Dr KURADUSENGE Martin**

Main Supervisor: **Dr KAYALVIZHI Jayavel** Co-Supervisor: **Dr KURADUSENGE Martin**

Date: 08 /10/2024 Date: 08 /10/2024

Signature: Signature:

The Head of Masters and Training

Dr. James Rwigema

Date :

Signature…………………

ABSTRACT

In response to escalating security access misuse within the aviation industry, this paper explores the development of an integrated security system utilizing real-time object identification algorithms and Internet of Things (IoT) technology to enhance airport safety. The research investigates how the YOLO algorithm, combined with IoT technology, can improve unauthorized access detection and overall security operations. Employing a holistic methodology, the study integrates theoretical frameworks with practical applications, analyzing the effectiveness of the YOLO algorithm for object recognition and IoT devices for real-time data collection in a simulated airport environment. Key findings indicate that this integration significantly enhances both the speed and accuracy of unauthorized access detection, facilitating more efficient monitoring through real-time alerts and improving operational effectiveness. the conclusion of the research demonstrates notable cost-effectiveness and scalability, suggesting its potential as a transformative solution for aviation security.

Keywords: aviation security, real-time object identification, YOLO algorithm, Internet of Things (IoT), unauthorized access detection, security systems, cost-effectiveness.

LIST OF ACRONYMS

IoT – Internet of Things

YOLO- You Only Look Once

LCD- Liquid Crystal Display

LED- Light Emitting Diode

GUI – Graphical User interface

R-CNN- Region-based Convolutional Neural Network

mAP - Mean Average Precision

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Contents

CHAPTER ONE: INTRODUCTION

1.1 Background

The aviation business has transformed rapidly due to technological advances, improving safety, operational efficiency, and passenger experience [1]. Security is becoming more important due to developing access misuse thus cutting-edge solutions must be included. Computer vision systems' real-time object detection can improve aviation security by identifying access misuses quickly and accurately. This background study examines real-time item recognition in an IoT environment utilizing the YOLO method [2]. The paper analyses the reasoning behind this method, evaluates relevant literature, and considers how this creative solution may affect aviation security [3].

The complexity of modern security issues requires advanced systems that can swiftly and reliably identify risks [4]. Security monitoring is proactive and automated with IoT sensors and cameras' real-time object detection. Security professionals can quickly detect and respond to suspicious objects or actions by analyzing visual data streams in real time, reducing security breaches and maintaining passenger safety [5]. In real-time object identification, computer vision, and IoT technologies, extensive research has helped build breakthrough security solutions. YOLO and other cutting-edge object identification algorithms function well in many applications. The YOLO model algorithm predict object bounding boxes and class probabilities in a single pass, revolutionizing real-time object detection[6]. Speed and accuracy make YOLO attractive for real-time surveillance, robotics, and autonomous vehicles.

IoT solutions for access identification and monitoring have been investigated in the aviation industry due to security concerns [7]. IoT-enabled sensors and cameras monitor airport and aircraft vital regions[8], [9]. These devices broadcast real-time data for automatic analysis and response. The integration of object detection technologies like YOLO with IoT devices can boost security. [10] devices are sensors and cameras strategically placed across airports and on aircraft. Data collection, transmission, and reception from crucial ecosystem places is their main goal [11]. Aviation IoT devices include sensors, cameras, connectivity modules, and data processing equipment. Their sophisticated network monitors, collects, and sends real-time data from critical places [12]. By providing data for analysis and response and enabling proactive access detection and mitigation, these IoT devices are leading security improvements.

A real-time object detection system using the YOLO technique in an IoT setting could improve aviation security. The system's constant visual data analysis detects suspicious objects, unauthorized access quickly. This method allows security staff to act immediately, improving security and reaction times. The value of this novel technology goes beyond unauthorized access detection. The automated system optimizes resource allocation and operational efficiency by reducing manual monitoring. The solution improves passenger experiences, security lineups, and operational workflows by streamlining security operations. Real-time object detection also meets industry and regulatory criteria for aviation security [11], [13].

Thus, real-time object identification using the YOLO method in an IoT environment can alter aviation security. YOLO's speed and precision, along with IoT sensors and cameras, can boost aviation security to new heights. Real-time face detection, automated alerts, and proactive responses ensure passenger safety and asset protection. This unique concept needs more study and development to reach its full potential. Aviation stakeholders, technological specialists, and regulators can work together to integrate real-time object detection systems into infrastructure. Advances in object detection algorithms, IoT technologies, and data processing methods, keeping it relevant and effective in the ever-changing aviation security field, can also improve this solution. [14]

1.2 Problem statement

In the aviation industry, which serves as a cornerstone of global connectivity and economic growth, there is an escalating and multifaceted security challenge that demands immediate attention Current security protocols heavily rely on manual monitoring and human intervention, presenting significant limitations in their ability to effectively counter the rapidly evolving security issues that airports and airlines face. This challenge encompasses issues such as unauthorized access, contraband smuggling, the persistent specter of terrorism, and the imperative for secure and streamlined passenger experiences.

Moreover, the aviation sector extends its operations both within airport confines and beyond, into the skies. Ensuring the safety and security of passengers throughout their journey, from the terminal to the aircraft, represents a formidable undertaking. The integration of IoT (Internet of Things) sensors and cameras offers the promise of real-time data collection and analysis. Yet, a comprehensive and intelligent security framework, equipped with real-time object detection capabilities, remains conspicuously absent.

Consequently, the airline struggles to implement a comprehensive and proactive security strategy. The airline's incapacity to swiftly identify and respond to emerging unauthorized access, in the absence of real-time object detection technology, results in delays, heightened security risks, operational inefficiencies, protracted security lines, and diminished passenger experiences. The absence of a robust security apparatus puts passenger confidence and the airline's brand reputation at risk, potentially culminating in financial losses and diminished competitiveness in the market.

In view of these daunting challenges, this research endeavors to propose and explore a novel solution an IoT-based real-time security system fortified with advanced object detection algorithms. Such an innovative approach holds the potential to revolutionize airline security by enabling the swift and precise identification of suspicious objects and individuals. By leveraging cutting-edge technology, such as the YOLO (You Only Look Once) algorithm, this research seeks to empower security personnel with real-time, actionable intelligence, thereby enhancing their ability to respond swiftly and effectively to emergent issuess in the aviation landscape.

1.3 Objectives

1.3.1 Main objective

To design, and develop a real-time security system with IoT-based object sensors and cameras at the airports for unauthorized access identification.

1.3.2 Specific Objectives

1. To develop an IoT-based architecture need to achieve unauthorized access detection at airport.
2. Integration of deep learning with IoT devices.
3. Design and develop a centralized monitoring system with an intuitive GUI for real-time analysis and response to security events.

1.3.4. Research Questions

1. How can IoT devices be strategically deployed at various points within an airport to maximize unauthorized access detection capabilities?
2. What deep learning techniques are most effective for analyzing data collected from IoT devices in the context of airport security?
3. How can the user interface of the monitoring system be designed to ensure ease of use and efficiency for security personnel?

1.5 Significance of Study

The importance of this study is drawn from its capability of bringing change in airports' security through the utilization of IoT and real time object detection among other features. The access misuse situation in the global security environment is evolving and getting more complex, and hence, there is need for higher level or pro-active security in airports. This paper will seek to fill this gap through proposing a real-time pragmatic security system that shall incorporate IoT based sensors and cameras along with YOLO object detection algorithm in order to improve face recognition and management.

As a potential benefit, operation of such a system could in general improve the safety and security status of passengers and employees inside airport territories and on board the airplanes. They consider the aspect of real-time monitoring and detection of the access misuse, which means that the security personnel can avoid such incidents as they happen and this could make a big difference in case the unauthorized access are neutralized before they turn into real incidents. In this sense, the above approach to security might help prevent terrorism, unauthorized access, and other acts of violence and interference of lives and property.

Secondly, the contribution of the study relates to the IoT and computer vision field, as this work illustrates possible usage of these technologies in the airport sector. The implementation of IoT sensors, cameras, and algorithm like YOLO for object detection in real-time application is a good reference for future development on similar domains. This can demonstrate practice possibilities and advantages of integration of these technologies for the resolution of complicated security issues as well as can encourage additional technologies' development and progress.

Furthermore, for airport, the implementation of this high level of security may have the effect of making it look more progressive and safety minded. This might help in getting confidence from the passengers and might be able to attract more customers most of whom would choose security over everything. Further, an enhancement in decision-making and policy making due to the accurate information the system presented on security events, leading to endless improvement on security indictment in airports.

1.6 Limitation of Study

As for the limitations of this study, several aspects across this novel real-time security system with an IoT-based object detection may pose consequences on the efficiency and transferability of the outcomes. Firstly, the concept of utilizing the hardware components such as cameras, sensors, Raspberry Pi is under the constraint since a hardware dysfunction might occur and require frequent maintenance. Such components become vulnerable to wear and tear, environmental influences, and equipment failure within an airport setting while running on a continuous basis and for such reasons, the uptime displays indicators of unreliability. Moreover, such hardware is costly to install and have to be maintained while in some airport settings there may not be the required technical knowledge for such applications.

In addition, the YOLO protocol for object detection requires a large amount of good quality data to train the algorithm. This is because YOLO is very fast and accurate, but can fail when there are uncertainties such as low light or crowded environment that is characteristic of airports. Occlusion and different appearance of an object may also cause problem to the algorithm where it may misclassify an object and result to either false positive or false negative. Preserving the algorithm's stability in different situations and conditions could be another difficult task that might not be systematically possible in the context of the study.

Thirdly, the formats of data transfer should also consider the problem of delay and the reliability of reporting on security events. However, issues regarding connectivity in the network; poor availability of bandwidth and, security access misuses may cause issues in data transmission. The implicit use of Cloud services is also an issue as data that is sensitive in its nature may be intercepted or hacked. Also, the centralized monitoring system will have a user interface that, despite being developed to incorporate the familiar Microsoft operating system, means that security personnel will spend much time mastering its use. Some organizational factors include the users' resistance to change, the constant training of people to understand the system and changes in the airport trade practices which affect the systems effectiveness and acceptance among the airport staff.

However, the restriction of the study to Rwandair Ltd and concrete operational environment may decrease the likelihood of the outcomes' applicability to other airlines and the airports with various security requirements and different infrastructure as well as with different legal conditions. This might mean that additional work would need to be done to adapt the kind of system described here to other kinds of setting, which may call for more research and development.

CHAPTER TWO: LITERATURE REVIEW

Rapid advances in real-time object identification and IoT technology have significantly transformed aviation security. This literature review examines major studies, academic articles, and industry reports on real-time object detection algorithms and their application in IoT environments within the context of aviation security. The review covers real-time object detection, IoT integration, their implications for the aviation industry, and identifies gaps in the current literature [15].

2.1 Real-Time Object Detection Algorithms

Real-time object detection techniques have revolutionized aviation security by enhancing the speed and accuracy of access misuse identification [16]. The YOLO algorithm is especially notable for its rapid and precise object recognition in video streams. YOLO divides an input image into a grid and predicts bounding boxes and class probabilities for each cell, allowing for efficient real-time processing [12], [17], [18]. Redmon characterize YOLO as a groundbreaking technique due to its superior accuracy and speed [6]. YOLO's ability to detect objects of varying sizes and types in real-time video sequences makes it highly applicable for airport and aircraft security applications. Subsequent iterations, such as YOLOv2 and YOLOv3, have further enhanced its performance and robustness [1]. Integrating YOLO into the proposed security system for airport. could significantly improve access misuse detection and response capabilities.

2.2 IoT and Aviation Security

IoT technologies are transforming aviation security by enabling seamless data collection, real-time analysis, and proactive decision-making. IoT sensors and cameras play a crucial role in enhancing access misuse detection and response mechanisms.

The proposed system utilizes IoT devices to gather real-time visual and environmental data, providing security personnel with immediate insights for addressing potential unauthorized accesss [19], [20] . IoT enhances security monitoring and management across various sectors [21], [22]. The integration of IoT devices allows security teams to receive real-time updates and make informed decisions, thereby improving overall security effectiveness [4].

2.3 Related Works

To better understand the advancements and gaps in the field, it is important to review related works:

Early Innovations in Object Detection: Initial studies focused on object detection techniques such as R-CNN and its derivatives, which laid the groundwork for real-time applications [22]. These early models were pivotal in advancing the algorithms used in real-time object detection.

Advancements in YOLO Algorithms subsequent studies have refined YOLO algorithms, leading to improvements in accuracy and processing speed [23]. YOLOv2 and YOLOv3, for example, have demonstrated enhanced performance in complex scenarios, making them suitable for security applications in dynamic environments [24].

IoT in Security: Literature on IoT applications in security highlights its transformative potential. Studies emphasize how IoT devices can integrate with surveillance systems to enhance unauthorized access detection and response. For instance, IoT-based systems have been used effectively in various sectors to improve monitoring and operational efficiency [25].

Case Studies and Implementations: Research on specific implementations, such as that involving airport security, highlights practical applications of IoT and object detection algorithms [26]. These case studies illustrate how integrated systems can improve security measures and operational workflows [27].

2.4 Implications for the Aviation Industry

The application of real-time object detection algorithms and IoT technologies in aviation security offers several benefits, including enhanced unauthorized access detection and response capabilities. The ability to swiftly and accurately identify potential access misuses allows security personnel to react promptly, thereby reducing the likelihood of security breaches [28]. Additionally, the proposed security system could increase operational efficiency by automating monitoring processes. Real-time data analysis minimizes the need for manual oversight, streamlining security operations and improving passenger experiences [29]. Research highlights that IoT technology can enhance operational efficiency across various industries [30]. The case study of aiports illustrates how integrating these technologies can optimize resource allocation, reduce operational costs, and minimize losses associated with security incidents [31].

2.5 Challenges and Gaps in Literature

Despite the promising potential of real-time object detection and IoT technologies, several challenges remain:

Cybersecurity: Ensuring robust cybersecurity for IoT devices and data processing is essential to prevent unauthorized access and data breaches.

Interoperability and Compatibility: Achieving interoperability and compatibility among diverse IoT devices within the aviation environment presents significant challenges.

Literature Gaps: The literature reveals gaps, including:

Limited integration studies focusing on real-time object detection and IoT technology in aviation security.

Insufficient empirical evidence regarding the practical effectiveness of these integrated systems.[23]

Comparative studies between traditional security systems and integrated approaches are also scarce. Regulatory and ethical considerations related to deploying such systems have not been extensively addressed. Addressing these gaps could provide valuable insights into the practical challenges, outcomes, and regulatory implications of deploying integrated security systems, thereby guiding effective implementation and policy development in the aviation security domain.

CHAPTER THREE: METHODOLOGY

In this chapter, we will focus the methodology employed in developing the real-time security system with IoT-based object detection for airport security. We will detail the hardware and software components used, as well as the procedures for system design, development, testing, and deployment.

3.1. System Overview and Block Diagram

The security system integrated various components to enhance airport security, including YOLO (You Only Look Once) object detection, camera sensors. The system was designed to capture and analyze real-time data to identify potential security access misuses [32].

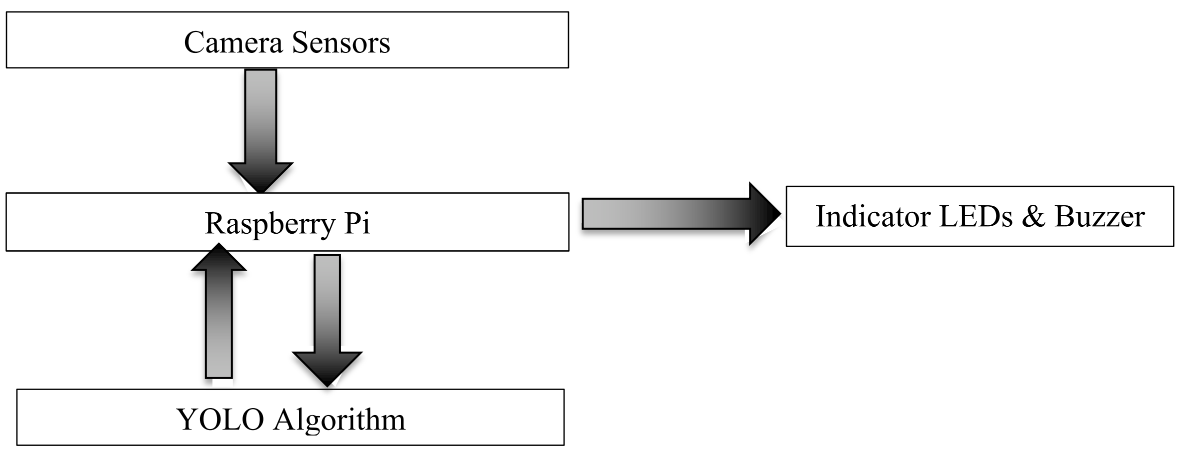

Figure 1: Hardware setup work flow

3.2. Hardware Setup

1. **Raspberry Pi Configuration**: The project began with setting up the Raspberry Pi as the central microcontroller [33], [34], [35]. This involved installing the operating system and necessary libraries, configuring network connectivity, and ensuring the device could handle real-time image analysis and sensor data processing.

   The Raspberry Pi was equipped with sufficient memory, storage, and cooling solutions to prevent overheating and ensure continuous operation.

2. **Camera Sensor Installation**: Camera sensors were installed at strategic locations. The cameras were calibrated to capture high-quality images in real-time. Placement was determined based on an assessment of security vulnerabilities and high-traffic areas. [18], [26], [36] The installation also included wiring and power supply considerations to protect against environmental factors.
3. **Indicator LEDs and Buzzer**: Indicator LEDs and a buzzer were added to provide immediate visual and auditory alerts. LEDs signaled the system status, while the buzzer alerted security personnel to unauthorized access. Placement and synchronization with the Raspberry Pi were meticulously executed to ensure effective alerting.

Below image, illustrate block diagram:

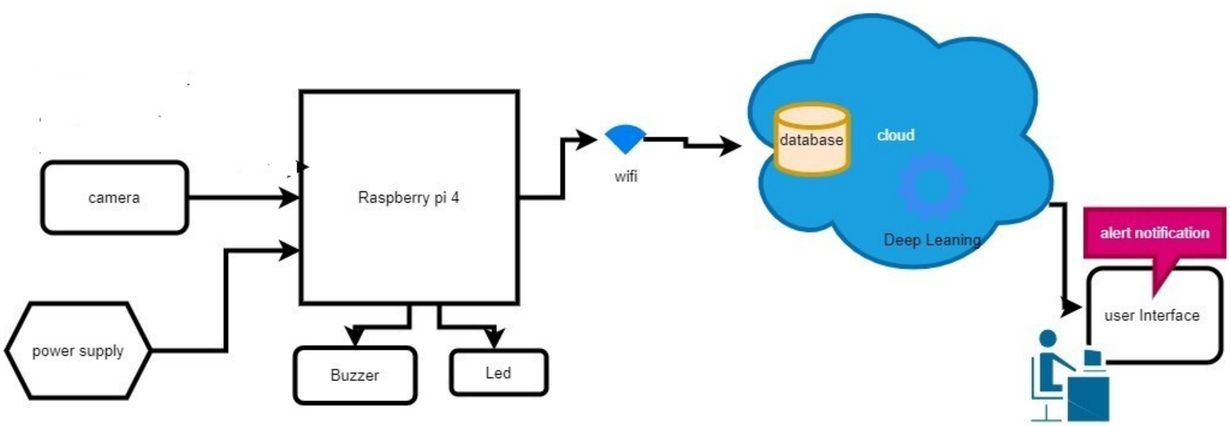

Figure 2: Block Diagram of the Real-Time Security System with Object Detection for Airports.

3.3. Software Development

1. **Python Programming**: Python was used for its flexibility and robust support for hardware integration [37]. The development involved coding modules for hardware interfacing, managing data streams from sensors, and executing real-time image analysis with YOLO. Extensive testing and debugging ensured the software's reliability and stability.
2. **YOLO Object Detection**: YOLOv8 was integrated into the Python code for real-time object detection. The algorithm processed images captured by the cameras to identify unauthorized individuals and prohibited objects. The YOLO model was configured with training data specific to airport security to optimize detection performance.
3. **SQLite Database**: An SQLite database was used to manage authorized personnel data. It stored records such as passport information and was designed with data integrity and efficiency in mind. The database included mechanisms for data validation and security.
4. **Graphical interface**: A graphical interface was developed to allow security personnel to monitor live camera feeds, view alerts, and manage system settings [5], [34]. The design focused on user experience, ensuring that the interface was intuitive and accessible from various devices.

3.4. Deep learning model

YOLO is a family of object detection models that leverage deep learning techniques to perform real-time object detection. [38]

3.5. Why YOLO?

YOLO is a popular object detection algorithm known for its speed and efficiency. Here's how it compares to other machine learning models for object detection:

1. **Speed**: YOLO is designed to be extremely fast. Unlike traditional object detection methods that may use a region proposal network (RPN) to generate potential object regions before classifying them, YOLO processes the entire image in one pass through the network. This makes it well-suited for real-time applications where speed is critical.[39]
2. **Single Network Architecture**: YOLO uses a single neural network to predict bounding boxes and class probabilities directly from full images in one evaluation. Other models, like Faster R-CNN, use multiple stages: one to generate region proposals and another to classify these proposals. YOLO's single-stage approach simplifies the process and enhances speed.
3. **End-to-End Training**: YOLO is trained end-to-end, meaning the entire model is trained together as a whole, from input to output. This contrasts with some other approaches that might involve separate training stages for different components such as region proposal networks and classification heads.
4. **Localization and Classification**: YOLO predicts multiple bounding boxes and class probabilities in a single forward pass. While it provides a good balance between accuracy and speed.
5. **Detection Accuracy**: Earlier versions of YOLO had trade-offs between speed and accuracy, often falling behind more complex models like Faster R-CNN in terms of precise localization and detection accuracy. However, newer versions of YOLO such YOLOv3, YOLOv4, YOLOv5, and YOLOv8 have made significant improvements in accuracy while maintaining speed.

3.6. Implementation and Deployment

1. **System Installation**: Following successful testing, the system was installed at the airport. Cameras, Raspberry Pi and other components were placed and calibrated to ensure optimal performance.
2. **Integration**: The installation included integrating hardware components and configuring software for real-time operation. Communication channels and data pathways were established to ensure cohesive system functionality.
3. **User Training**: Security personnel underwent training to familiarize themselves with the system. Training included practical demonstrations, real-time simulations, and instructions on interpreting alerts and managing the system.

3.7. System Testing

1. **Functionality Testing**: The system's core functionalities, including YOLO object detection were tested to verify their effectiveness. Test scenarios simulated various security access misuses to ensure accurate detection and response. The accuracy of object detection and system responses were evaluated under controlled conditions. In this research we used Comprehensive Performance Measure(mAP**).** mAP aggregates the performance across all classes and provides a single score that summarizes how well the model performs in detecting all object classes. It combines the precision-recall curve for each class and then averages these values, making it a holistic metric for object detection.

$$\text{mAP} = \frac{1}{C}\sum_{i=1}^{C}\text{AP}_i$$

where C is the number of classes and AP_i, is the average precision for class i.

When evaluating YOLOv8 or any object detection model, mAP provides a well-rounded assessment of model performance. It accounts for both the correctness and completeness of the detections across all object classes, making it a robust choice for summarizing model effectiveness

2. **Database Validation**: The SQLite database was tested for accuracy in storing and retrieving personnel records. Validation involved cross-referencing data and simulating access scenarios to ensure that only authorized individuals could enter restricted areas.
3. **User Interface Testing**: The interface was tested for usability and responsiveness. Security staff provided feedback to refine the interface, ensuring it was effective for real-time monitoring and control.

3.8. Ongoing Monitoring and Maintenance

1. **Ongoing System Monitoring**: Post-deployment, a dedicated team monitored the system's operation, analyzed camera feeds, and managed alerts. Regular health checks were performed to maintain system reliability.[40], [41]
2. **Data Backup and Security**: Data backups were conducted regularly to prevent loss. Security measures, including encryption and access controls, were implemented to protect data integrity and confidentiality [23], [42].
3. **Software Updates and Improvements**: Periodic software updates were introduced to enhance performance and address vulnerabilities. The update process included testing to ensure system stability and effectiveness [7], [43].

CHAPTER FOUR: RESULTS

The results of the real-time security system with object detection, designed to enhance security in airport areas, are presented in this section. The project involved the development and testing of a system that detects individuals and confirms their identity in real-time. The evaluation of the system's performance included the analysis of accurate statistics and reports.

4.1 Proposed hardware circuit

A successful hardware design has been meticulously developed to optimize and clarify the communication flow between various hardware components. This design aims to enhance the efficiency and effectiveness of data exchange within the system, ensuring that each component interacts seamlessly with others. By addressing key aspects such as signal integrity, data throughput, and synchronization, the design facilitates robust and reliable communication pathways.

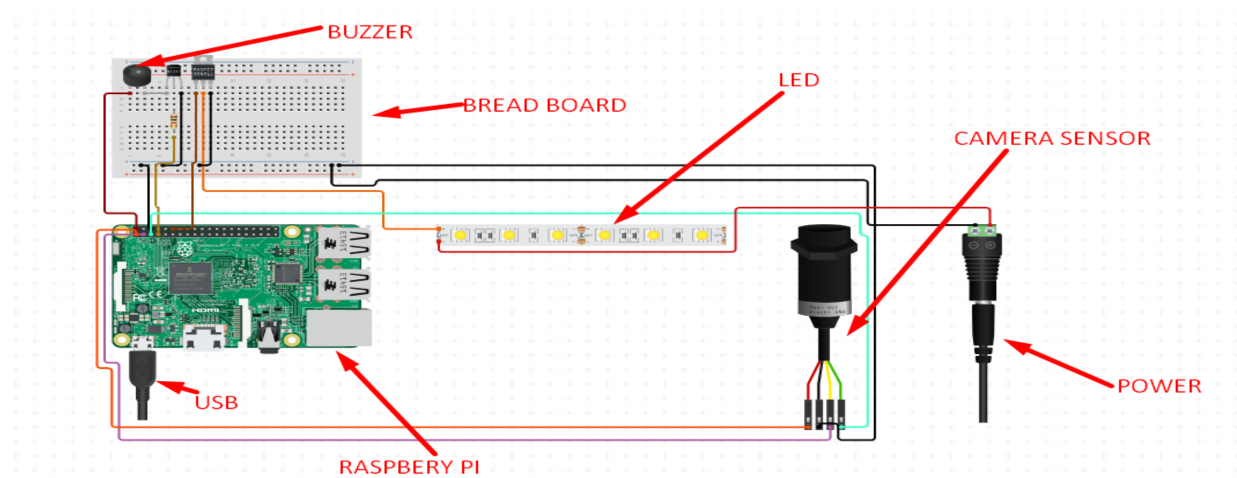

Figure 3: System hardware design

4.1.1. Key Aspects of the Hardware Design:

Signal Integrity: The design incorporates advanced techniques to minimize signal degradation and interference, ensuring that data transmitted between components remains accurate and consistent. High-quality connectors, shielding, and impedance matching are employed to preserve signal fidelity.

Data Throughput: The hardware architecture is engineered to handle high data transfer rates efficiently. This involves optimizing bus widths, clock speeds, and data paths to accommodate the volume and speed of data required for real-time processing or high-bandwidth applications.

Synchronization: To maintain coherent communication between components, the design integrates precise timing mechanisms and synchronization protocols. This ensures that data exchanges occur at the correct intervals and that all components remain aligned in their operations.

Modular Integration: The design supports modular integration, allowing different hardware modules to be easily added or replaced without disrupting the overall system. This modularity simplifies system upgrades and maintenance, facilitating long-term adaptability.

Error Handling: Advanced error detection and correction mechanisms are built into the design to identify and address communication issues promptly. This enhances system reliability and minimizes the risk of data corruption or loss.

Scalability: The design is scalable, accommodating future expansions or modifications. This flexibility ensures that the hardware can evolve with changing requirements or technological advancements, providing a sustainable solution.

4.1.2. Benefits of the Design:

Enhanced Performance: The optimized communication flow improves overall system performance, reducing latency and increasing processing speed.

Increased Reliability: By ensuring robust and error-free communication, the design enhances the reliability of the system, reducing the likelihood of failures or disruptions.

Ease of Integration: The modular approach simplifies the integration of new components or systems, making it easier to adapt to new technologies or requirements.

Cost Efficiency: Effective design reduces the need for costly troubleshooting and maintenance, leading to cost savings over the system's lifecycle.

4.2. Prototype implementation

The output of the prototype demonstrates that the face detection monitoring system utilizing YOLOv8 is highly recommended for addressing the current issues. The advanced capabilities of YOLOv8 provide improved accuracy and efficiency in detecting and monitoring faces, making it a superior solution compared to previous methods. This recommendation is based on the system's ability to deliver precise and reliable results, thereby effectively solving the existing problems and enhancing overall performance

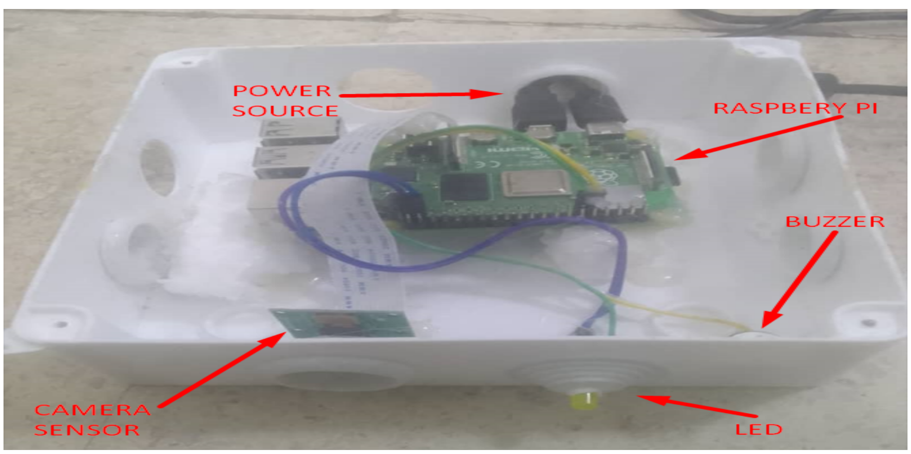

Figure 4: Prototype results

4.3. Yolov8 Model result calculations

The output of model illustrate that the object detect is the person with maxim sped of 2.7 ms preprocess, 235.5ms inference, 4.0 ms postprocess where confidence and class were represented as final results.

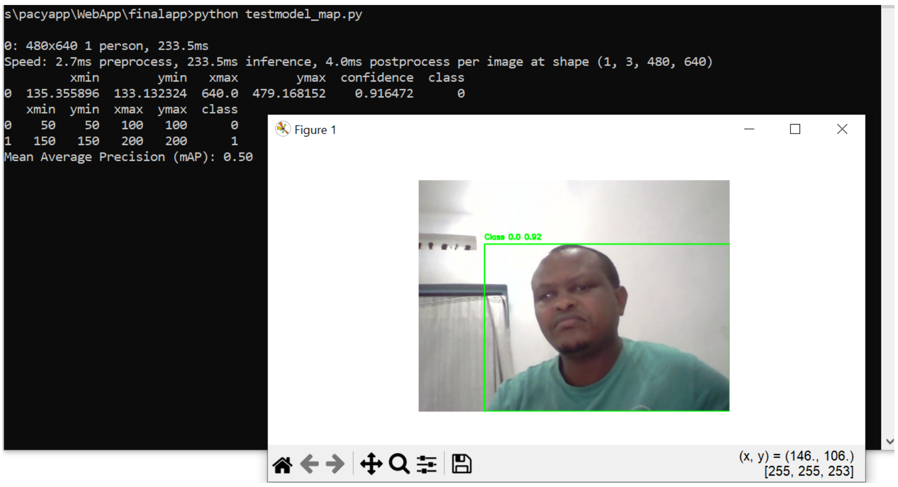

Figure 5 : Mean average precision results

4.3 Face detection

The deployment of multiple camera sensors equipped with advanced object detection algorithms allowed the system to identify individuals with high precision. Each individual's identity was promptly confirmed, ensuring that the object detected with highest confidence.

The successful object detection and identification process played a pivotal role in enhancing security within the airport environment. This can help security organ to identify number of objects detected where camera is set and provide clear statistics.

Below figure illustrate how face detection works in the proposed solutions:

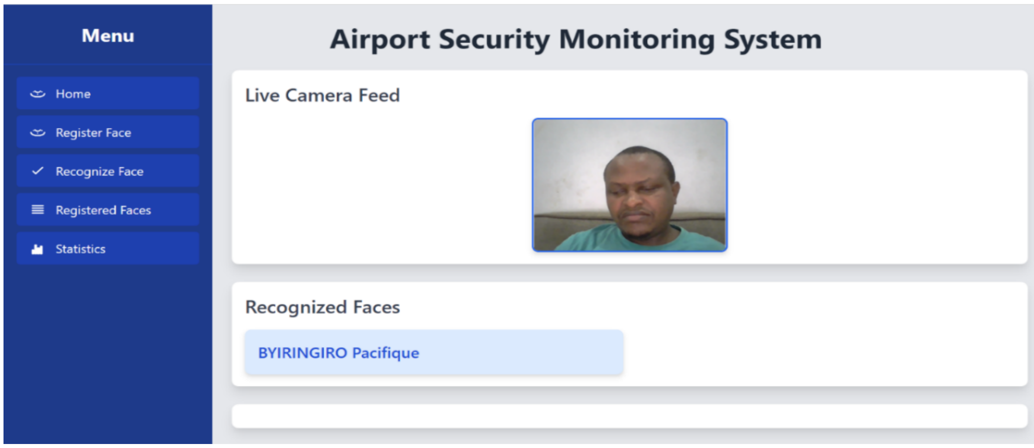

Figure 6: Face recognition interface

4.3 Register authorized personnel

Security team will have ability to register authorized people. This will help them to increase number of allowed accesses in case needed. Below image, illustrate how authorization will be provided:

Figure 7: *Register new personnel*

4.4. Display authorized personnel's

Interface for displaying authorized personnel was developed specifically to assist the security team in tracking and managing stored records efficiently. This user-friendly interface is designed to provide a comprehensive and real-time view of personnel data, facilitating quick access to relevant information and enhancing overall security operations

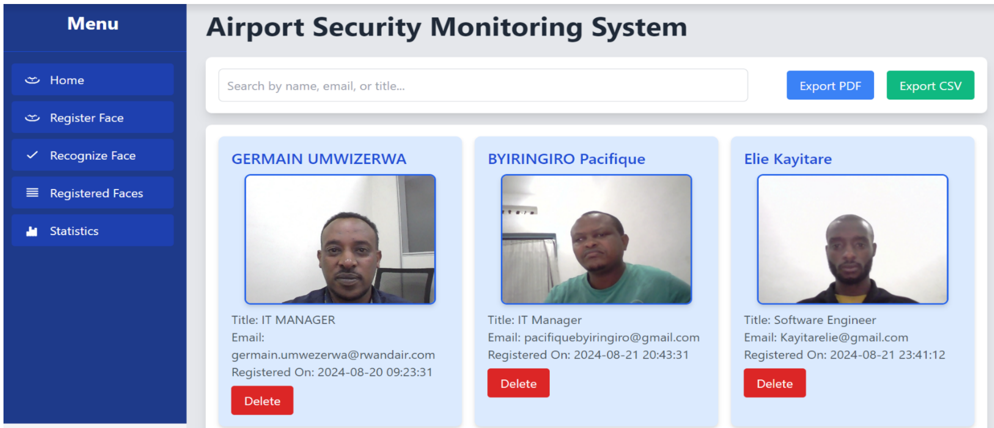

Figure 8: ***Register new personnel***

4.5. Statistics and reports

A comprehensive Statistics and Report Interface was developed to streamline the process of delivering timely updates to the security team. This advanced interface is designed to provide real-time insights and detailed reports, ensuring that the security team receives up-to-date information quickly and efficiently. The system is able to provide daily and weekly report regarding authorized and unauthorized people.

Figure 9: ***Statistics interface***

The system can generate reports in PDF format, providing a polished and professional appearance that is perfect for presentations and formal documentation. PDF reports are ideal for sharing with stakeholders, as they preserve the formatting and layout of the data, ensuring consistency across different devices and platforms. The generated PDFs can include visual elements such as charts and graphs, and are easily accessible and printable, making them suitable for both electronic and hard-copy distribution.

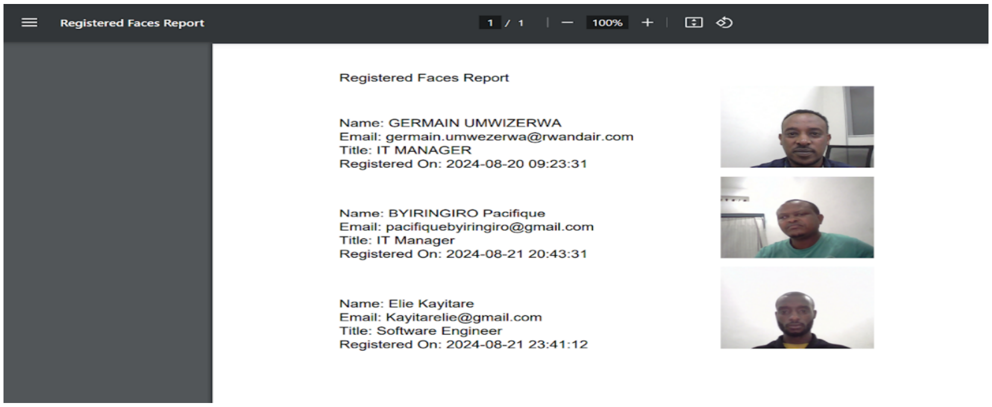

Figure 10: Authorized personnel's PDF report

In addition, the system offers the option to generate reports in Excel format. This format is highly versatile and facilitates in-depth data analysis and manipulation. Users can interact with the raw data directly, use Excel's powerful functions and formulas, and create custom charts and graphs. The Excel reports are particularly useful for users who need to perform detailed data analysis, generate pivot tables, or integrate the data with other applications and workflows. This format supports data export and import, making it easier to work with large datasets and perform further calculations.

Name	Email	Title	Registration Date
GERMAIN UMWIZERWA	germain.umwezerwa@rwandair.com	IT MANAGER	20-08-24 9:23
BYIRINGIRO Pacifique	pacifiquebyiringiro@gmail.com	IT Manager	21-08-24 20:43
Elie Kayitare	Kayitarelie@gmail.com	Software Engineer	21-08-24 23:41

Figure 11***: Authorized personnel's Excel report***

CHAPTER FIVE: DISCUSSION AND CONCLUSION

The results of the real-time security system with IoT-based object detection align closely with the predefined research objectives. The primary objective was to design, develop, and test a system that would enhance aviation and airport security. This objective, in conjunction with the specific objectives of system design, integration, data transmission, and central monitoring, shaped the project's outcomes.

The system's design successfully integrated a network of IoT sensors and cameras at critical locations within airports and on aircraft. The high-resolution cameras captured visual data from various airport zones, both on the ground and within aircraft. This comprehensive network was equipped with microcontrollers and local data processing units that analyzed data on-site, ensuring a rapid response to potential hazards.

The system's architecture was inherently scalable and interoperable, enabling it to adapt to changing security needs and seamlessly communicate with a centralized monitoring system. The collected data was securely stored for future analysis and compliance reporting, bolstering the system's potential in enhancing aviation security.

Furthermore, the system integrated advanced object detection algorithms, with a primary focus on the YOLO (You Only Look Once) method, renowned for its speed and accuracy in real-time object detection. The synergy between the IoT-based architecture and the YOLO algorithm proved successful, enabling the system to swiftly and accurately identify objects and individuals in real time.

Efficient data transmission protocols were established to facilitate data transfer from IoT sensors and cameras to the central monitoring system. These protocols minimized latency and ensured data reliability, guaranteeing a swift response to security events. The central monitoring system, as stipulated in the research objectives, provided security professionals with access to real-time data streams and YOLO-generated insights. The system's intuitive interface empowered security personnel to swiftly analyze visual data, detect suspicious objects or actions, and respond proactively to security events.

In practical terms, the successful accomplishment of these research objectives translates into an innovative and efficient security system for the aviation and airport industry. The system's real-time object detection capabilities have the potential to revolutionize security practices, as it empowers security professionals to promptly identify and respond to unauthorized accesss, ultimately reducing security breaches and enhancing passenger safety.

Moreover, the system optimizes resource allocation and operational efficiency by reducing the need for manual monitoring. This not only streamlines security procedures but also results in improved passenger experiences and operational workflows. In this regard, the system aligns with industry and regulatory standards, reinforcing its significance and effectiveness in the ever-evolving field of aviation security.

In conclusion, the results of the real-time security system, in alignment with the defined research objectives, indicate a significant advancement in aviation and airport security. The successful integration of IoT sensors, cameras, and advanced object detection algorithms has the potential to transform security practices, enhancing unauthorized access detection and response while optimizing resource allocation and operational efficiency. These results mark a substantial step forward in the ongoing effort to ensure the safety and security of the aviation industry.

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