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Research Thesis Title:

Students behavior monitoring using IoT and Computer Vision in Rwanda Schools

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

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December, 2023

Declaration

I Ndayisenga Emmanuel, Master 'student from African Center of Excellence in internet of things, at University of Rwanda. I declare that this research thesis is my own original work and it has never been presented elsewhere.

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Bonafide certificate

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Acknowledgment

I would like to express my deepest gratitude to my esteemed supervisors, **Dr. MASABO Emanuel** and **Dr. GASHEMA Gaspard** for their invaluable guidance, mentorship, and unwavering support throughout my research. I am also expressing my gratitude to **Tubimenye Smart Solution Ltd** for granting me full access to their IoT infrastructure, a critical resource that significantly enhanced the depth and scope of my research. Their constant support has been pivotal to the success of this project.

Additionally, I extend my thanks to all those who assisted me in various forms in one way or the other, through advice, feedback, or practical contributions. The collaborative efforts of everyone involved have been instrumental in helping me to reach this milestone.

Looking ahead, I welcome and appreciate any future contributions that will further contribute to the realization of this project, aimed at applying this innovative solution to improve the daily lives of Rwandans. Together, we aspire to make a meaningful impact on the community through the successful implementation of this project.

Abstract

This thesis focused on the use of Internet of Things (IoT) technology and computer vision to develop a student behavior monitoring system in Rwandan schools. The main objective is to automate the tracking of attendance, to locally and remotely analyze behavioral trends, and enhance the way that discipline is monitored in schools. Computer vision and edge processing are used by the system to safely gather and analyze attendance records. Parents automatically receive real-time SMS notifications regarding student absences. To foster communication, behavior reports are monthly created and sent to respective parents via email.

By mean of machine learning techniques and edge processing technology for real-time analysis, computer vision technology uses for face recognitions. The system makes use of the ESP32 CAM to effectively take pictures at the edge, enabling faster processing and alleviate the requirement for large-scale data transfer. Using edge processing, the system may quickly assess and react to events by identifying and recording aberrant activity, such as sudden noise. The system's quick analysis notifies authorized staff members to take direct required action.

The use of remote monitoring technologies gives the staff members the ability to keep an eye on actions in the classroom and foster a safe learning environment. Improved attendance tracking, more stringent discipline monitoring, tailored child support and intervention, early parent-child involvement, and the early detection of abnormal behavior using edge-based analysis are among the achieved results. The developed system surpasses manual methods by automating the generation of comprehensive reports, eliminating the need for continuous human intervention. In contrast to some of existing system which are web based, it fosters parental involvement through real-time SMS updates and emailed reports, addressing the limitation of parent access to information. Notably, the system excels with edge processing features, providing daily updates and customizable configurations tailored to specific domains. This ensures an enhanced, user-friendly experience for academic and professional institutions.

Key words: Internet of Things (IoT), computer vison, ESP32 CAM, Machine learning, Edge processing

List of Acronyms

AI: Artificial Intelligence

API: Application Programming Interface

BLE: Bluetooth Low Energy

CNN: Convolutional Neural Network

CV: Computer Vision

Db: Database

DNN: Deep Neural Network

ECS: Embedded computing system

ESP32-CAM: Espressif Systems' Programmable System-on-Chip with Camera

GSM: Global System for Mobile Communications

IoT: Internet of Things

ML Kit: Machine Learning Kit (a mobile SDK provided by Google for incorporating machine learning features into applications)

Pdf: Portable Document File

PDL: Program Design Language

SMS: Short Message Service

V: Volts

Wi-Fi: Wireless Fidelity

YOLOv5: You Only Look Once version 5

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CHAPTER I: GENERAL INTRODUCTION

1.1 Background

Technology integration in educational settings has drawn a lot of attention recently, offering chances to enhance the learning environment in a multiple facet. Monitoring student conduct is one area that is especially important since it is vital to upholding discipline and promoting a safe environment, and maximizing the educational experience and comfort [1]. Conventional behavior monitoring techniques frequently depend on subjective evaluations and manual observations, which can be laborious and prone to biased [2].

In order to tackle these problems, our research focuses on developing a standalone and an automated student behavior monitoring system in Rwandan schools using computer vision and the Internet of Things (IoT). Through the use of IoT sensors and computer vision algorithms, this system seeks to enable objective, real-time monitoring of student behavior. This will enable teachers and administrators to swiftly intervene on time, provide feedback, and carry out appropriate interventions as needed [3][4]. This study's primary goal is to create and put into place a complete framework for tracking student behavior that leverages computer vision techniques with Internet of Things (IoT) sensors. The system will record and analyze student behavior patterns, including actions like attendance, positive or negative intentions, engagement, and compliance with rules and regulations of institutions, by strategically placing IoT sensors and cameras in classrooms and strategical areas.

Additionally, the purpose of this study is to evaluate the designed system's viability and efficacy inside Rwandan educational institutions. The objective of this study is to offer an understanding of the viability and possible advantages of implementing this innovative technology in educational settings by means of field experiments and data collection on system performance, usability, and impact on student behavior and overall academic performance.

In general, the main goals of this research are to add to the corpus of information already available in the field of educational technology and offer useful suggestions for utilizing computer vision and IoT to enhance the observation of student behavior in Rwandan schools. This technology has the ability to enhance the learning environment, encourage discipline, and eventually raise student academic accomplishment by creating an automated and impartial method of behavior monitoring and give the parent the assurance of security of their children.

1.2 Motivation

In recent years, the use of the latest technology in educational settings has become more and more common, offering exciting prospects to enhance several facets of the learning environment [5]. Among these, keeping order, establishing a safe an inclusive atmosphere, and optimizing the learning process all depend on tracking of student behavior, which has emerged as a critical area the need a lot of focus. However, old fashioned behavior monitoring methods often rely on subjective evaluations and manual observations, which can be biased and time-consuming.

The goal of this research is to create an AI based automated student behavior monitoring system specifically designed for Rwandan schools by utilizing the capabilities of computer vision and the Internet of Things. Through the use of IoT sensors and computer vision algorithms, the system aims to provide objective, real-time surveillance of student behavior [6]. This would allow teachers to step in quickly, offer constructive support on time, and carry out critical interventions in a proactive manner as needed.

Using Internet of Things (IoT) sensors and cameras, the suggested system will be strategically placed across classrooms and strategically pointed areas to record and examine different student behavior patterns and school activities. These patterns include keeping an eye on students' attendance and compliance with rules and planned invigilation. Through the collection of information on various fronts, the system hopes to give teachers and administrator thorough understandings of student conduct and the resources they need to manage and support their students in a proactive manner.

1.3 Problem Statement

Traditional techniques of keeping an eye on student conduct in Rwandan schools mainly rely on manual observations, which are more frequently biased, tiresome, time-consuming, and subjective. These invigilation techniques fall short of giving educators objective, up-to-date information regarding student behavior, which makes it more difficult for them to act appropriately, give timely feedback, and carry out the necessary interventions. In addition, the absence of automated behavior monitoring systems reduces the ability to uphold discipline, provide a secure learning environment, and enhance the educational process.

This research is aimed to tackle these issues by developing and implementing an automated system for monitoring student behavior in Rwandan schools using IoT and computer vision technology. Real-time recording and analysis of student behavioral trends, including attendance, attentiveness, involvement, and obedience to school rules and regulations, is the goal of the system. The system will strategically combine computer vision algorithms and Internet of Things sensors to give educators, administrator and parents objective and meaningful data. This insightful data will enable them to implement evidence-based interventions, offer tailored assistance, and react swiftly to behavioral challenges and prevent escalation of bad behavior.

1.4 Study Objectives

1.4.1 General Objective

The main goal of this research is to take advantages computer vision and Internet of Things technologies to create and implement an automated system for monitoring student behavior in Rwandan schools. The purpose of this technology is to improve the whole process of learning environment by offering objective, real-time insights about student behavior and enabling timely interventions.

1.4.2 Specific Objectives

1. Create an autonomous system for monitoring student behavior in Rwandan schools using a combination of Internet of Things (IoT) technology, computer vision algorithms, and artificial intelligence (AI).

2. Integrate edge processing capabilities into the system to enhance efficiency and enable real-time data processing at the device and sensor level. Facilitate continuous observation of student conduct for prompt response.

3. Establish a system-wide communication infrastructure to enable real-time selective communication among parents, teachers, and administrators.

By achieving these specific objectives, the research seeks to establish the effectiveness and viability of leveraging IoT, edge processing and computer vision technologies for student behavior monitoring, with a focus on enhancing discipline, promoting a conducive learning atmosphere, and ultimately improving overall educational outcomes in Rwandan schools.

1.5 Hypotheses

The strategical integration of powerful computer vision algorithms, edge devices, IoT sensors, and AI-driven analytics into a distributed edge computing architecture makes it feasible to monitor student behavior in educational settings with highest accuracy and context awareness. With the use of AI algorithms, this all-in-one inclusive framework allows for the real-time study of intricate behavioral patterns, revealing subtle signs of deviation in student engagement, and learning interactions. The system's ability to deliver timely, individualized interventions is improved by the inclusion of AI-driven analytics at the edge, creating a more responsive and adaptable learning environment. This autonomous method maintains strict data privacy measures while drastically reducing latency and optimizing bandwidth utilization to ensure effective and secure student behavior monitoring.

This expanded hypothesis highlights how AI-driven analytics within an edge computing architecture can be revolutionary, providing more subtle insights into student behavior than current traditional measures. The study intends to show how the system can adjust to changing classroom dynamics, offer individualized feedback, and create a safer, welcoming and encouraging learning environment by incorporating AI capabilities. This will ultimately improve the quality of education offered to students in Rwandan schools. The research aims to demonstrate the usefulness and effectiveness of edge processing technology with AI integration in enabling thorough student behavior monitoring and fostering academic brilliance through empirical validation.

1.6 Study Scope

This research study focuses on the development and deployment of a state-of-the-art computer vision and Internet of Things (IoT) system integrated with artificial intelligence (AI)-driven analytics for monitoring student behavior in Rwandan schools. By utilizing a distributed edge computing architecture for real-time data analysis, the study seeks to accomplish extremely accurate and context-aware behavior monitoring of students.

Developing an integrated IoT and computer vision infrastructure, using machine learning algorithms to analyze student adherence to school rules, automating remote control for targeted interventions, and selectively sending out real-time SMS notifications for student absences to respective parents are all important parts of the system. The study also considers cultural variables, ethical considerations, technological infrastructure requirements, and privacy issues. Enhancing disciplinary management, creating safe learning environments, and providing insightful information for future studies and policy decisions in Rwandan schools are the goals of this project.

1.7 Significance of the Study

The study is more significant because it can transform Rwandan schools' educational system by tackling important and challenging issues with student behavior monitoring. Using IoT and computer vision technology to construct a student behavior monitoring system offers several important contributions in various facets:

1. Automation of Attendance Monitoring

Automating attendance tracking accurately streamlines the process, guarantees accurate records, and lessens administrative burden—all of which contribute to a more productive learning environment with highest quality education delivery.

2. Analysis of Behavioral Trends

The system's ability to evaluate behavioral patterns through the use of machine learning algorithms gives it important insights into how students behave. Teachers, administrators and parents may find this information essential for carrying out focused interventions.

3. Discipline Management Improvement

By focusing on real-time monitoring and analysis of student behavior, the system aims to enhance discipline management in schools. Early detection of abnormal behavior allows for timely intervention and support.

4. Effective Communication with Parents

With the help of monthly behavior reports sent by email and real-time daily SMS notifications for student absences, the system makes it easier for parents and students to stay in touch. This guarantees that parents take an active role in their child's education and behavior modification and informed decision.

5. Remote Monitoring for Improved Classroom Environment

The incorporation of remote monitoring techniques empowers administrative staff to observe classroom activities from a distance, fostering a conducive and ensure a secure learning environment.

6. Data-Driven Decision-Making

The system empowers educators and administrators with data-driven insights, enabling informed decision-making. This can lead to more effective educational policies and good practices.

1.8 Organization of the Study

The study is broken up into multiple components and organized using an organized method. An outline of the study's goals, background, and research challenge is given in the introduction. The literature review examines the state of the art in terms of computer vision, IoT, and student behavior monitoring systems, as well as their applications in learning environments from existing systems and attempts. The technologies utilized to implement the student behavior monitoring system, data gathering techniques, and research design are all covered in detail in the methodology section.

The section of implementation and results section present the practical application of the system, including the use of ESP32 CAM, machine learning algorithms, and study outcomes. The discussion section analyzes findings in the context of existing literature, addressing limitations and highlighting implications for educational practices. The conclusion summarizes key findings, contributions, and implications, emphasizing the potential impact on discipline, learning environments, and academic outcomes finally the recommendation for future research is outlined.

CHAPTER II: LITERATURE REVIEW

2.1 Overview of the Internet of Things (IoT) and embedded computing systems

A network of physically distributed connected objects, such as machinery, cars, appliances, and other tangible objects, that are outfitted with sensors, software, and network connectivity is referred to as the "Internet of Things" (IoT). These things are able to collect and exchange data thanks to the latest technology. The Internet of Things (IoT) is the concept of connecting things and facilitating real-time communication between them to allow for automation and smooth integration.

Sensor technology enables data collection from several distributed sources and internet distribution, enabling real-time monitoring, analysis, and control. This interconnectedness opens up a wide range of potential applications across industries, such as healthcare, transportation, manufacturing, and education as well. [7]. Through facilitating remote learning, encouraging personalized and interactive learning, streamlining resource allocation, and enhancing student safety and security, IoT in education has the potential to completely change classrooms.

IoT in education offers a number of benefits and opportunities that are well worth exploring. IoT technology has the potential to greatly enhance learning environments in different ways. First, by providing interactive, customized information that is tailored to each student's individual needs, IoT can enhance students' educational experiences in his academic journey. It facilitates real-time feedback and adaptive learning, which raises student comprehension and engagement. Second, IoT can boost operational efficiency in educational institutions by streamlining workflows, automating administrative tasks, and optimizing resource allocation saving environment.

This allows educators to focus more on helping kids and teaching. Not to mention, IoT fosters innovative teaching strategies by offering fresh platforms and resources for collaboration, virtual role-playing, and immersive learning experience. Numerous current applications show off the potential of IoT in education: classrooms equipped with smart devices for interactive learning, behavior monitoring systems that track and analyze student performance, and campus management systems that facilitate efficient resource and security monitoring are just a few examples of how this technology can be used in education setting.

2.2 Review of existing behavior monitoring systems and techniques

The demand for better attendance tracking, improved discipline administration, and the creation of inclusive and safe learning environments led to the decision to do research on student behavior monitoring using IoT and computer vision in Rwandan schools. This project aims to enhance communication between schools and parents, automate attendance procedures, and evaluate behavioral trends using state-of-the-art technologies like edge processing, IoT and Computer Vision.

Numerous relevant works that have been unearthed have influenced the theoretical underpinnings of this research. They focus on using computer vision technology for moving object recognition to identify student actions an intent in classrooms. The research makes recommendations for deciphering student actions and behaviors [8].

The subject of student conduct and emotional patterns in an online learning environment examined, the study offers deepest insights into monitoring students' levels of happiness using behavioral and emotional analysis [9].

The relevant research investigates the application of Convolutional Neural Network (CNN) techniques to identify emotional expressions on students' faces. These works shed light on how students' emotions might be assessed using deep learning algorithms [10].

In the study of face recognition attendance tracking system that makes use of combined deep learning and computer vision technologies. The use of facial recognition to track attendance in surveillance situations is clarified [11].

The research delve into the use YOLOv5 object detection model to investigate behavior recognition in smart classrooms with multiple students. This research offers methods for comprehending how students behave in a classroom [12].

All of these references add to the body of existing knowledge already available on behavior tracking, IoT, and computer vision in educational environments. Their theoretical underpinnings and perceptive observations boosted the motivation behind this study, which seeks to further the field of student behavior monitoring in Rwandan schools by expanding on the body of currently existing knowledge.

2.3 Discussion of IoT and computer vision applications in education and student behavior monitoring

A study of the literature on IoT and computer vision-based student behavior monitoring in Rwandan classrooms identifies a number of important researches that demonstrate the uses and advantages of these technologies in educational settings. All of these studies provide insightful information about examining the attitudes, behaviors, attendance, and learning patterns of students.

The study investigates and develop methods for identifying and understanding student behaviors within the classroom setting through the utilization of moving target detection techniques. The study aims to explore innovative approaches that leverage motion analysis to recognize and categorize various behaviors exhibited by students during classroom activities [8]. This study offers a way to analyze students' activities and behaviors in the classroom in real time by using computer vision technology.

The detection of students' behavioral and emotional patterns in an online learning environment is the subject of the research paper [3]. This study attempts to evaluate students' engagement and level of satisfaction by keeping an eye on their actions and feelings. In order to do this, a variety of methods, including data mining, machine learning algorithms, and sentiment analysis, are used to analyze student reactions and interactions within the e-learning platform.

Convolutional neural networks (CNNs) are used to recognize the facial emotions of students. The research offers a technique to comprehend and analyze student emotions by gathering a dataset of face photos representing various emotions, training the CNN model on this dataset, and using it on real-time or static facial images [10].

Creating a face recognition attendance monitoring system that makes use of deep learning and computer vision technologies with the help of a face dataset and effective training of a deep learning model, the system allows real-time face detection and recognition for attendance tracking [11].

The YOLOv5 object detection model is used to identify learning behavior in smart classrooms with multiple students [12]. By recognizing and tracking objects or actions in real-time photos and videos, this model enables behavior recognition. In order to detect and identify these behaviors in a smart classroom setting, the researchers strategically trained the YOLOv5 model on a set of behavior-related objects or activities.

The domains of Internet of Things and computer vision-based student behavior monitoring in educational environments have advanced significantly as a result of the aforementioned investigations. Through in-depth investigation and analysis, these studies explore a wide range of aspects of student behavior monitoring, providing comprehensive insights and generating novel opportunities for assessment and ongoing improvement.

One major area of concern is the evaluation of student conduct. These conducted researches look into different measures and standards for evaluating student behavior in classroom settings. Using IoT and computer vision technologies, researchers can develop novel methods for measuring factors like involvement, attention, and engagement in real-time. This helps educators and administrators to get a complete picture of students' behavior, identify areas of concern, and modify their teaching methods accordingly.

These studies also look at various methods of identifying emotions and assessing student involvement. By analyzing non-verbal cues like facial expressions, researchers can ascertain students' emotional states and level of satisfaction with the learning environment. With this information, teachers can create a warm, encouraging and engaging environment that caters to the individual requirements of every student.

One key use of IoT and computer vision-based student behavior analysis is attendance monitoring. Conventional methods of taking attendance can be tedious and prone to mistakes. However, by combining IoT devices and computer vision algorithms, researchers have developed automatic attendance systems that precisely track student presence and absence. This simplifies administrative processes and provides insightful data for analyzing attendance patterns and identifying any issues that could affect students' academic performance.

In conclusion, the research listed advances our understanding of IoT and computer vision-based student behavior monitoring. They provide precise insights into assessing student conduct, quantifying contentment, recognizing feelings, keeping an eye on attendance, and comprehending and keep track on changing behaviors.

By harnessing the potential of these latest technologies, educational institutions can create an enriched learning environment that fosters better educational outcomes and provide supports to students according his individual needs.

2.4 A Unified Approach with Emphasis on Edge Processing and Real-Time Communication

The progress in IoT and computer vision applications has revealed significant gaps in existing systems, particularly in Rwandan schools, where a comprehensive solution integrating attendance tracking, behavioral monitoring, and parent communication is lacking. Two main gaps are found: the ineffectiveness of real-time communication with parents in the current systems, which calls for improvements for timely updates and reports; and the requirement for optimized edge processing to overcome centralized processing challenges and enhance real-time analysis, ensuring prompt response to classroom events. By creating a unified system that prioritizes edge processing for instantaneous analysis, this research aims to close these gaps and provide a user-friendly experience for academic and professional institutions. At the same time, it addresses issues with the present systems that are used in Rwandan schools.

This subsection highlights two key deficiencies in current Rwandan school systems: firstly, the requirement for improved edge processing to address challenges associated with centralized processing, thereby facilitating enhanced real-time analysis and prompt responses to classroom events; and secondly, the inefficiency of real-time communication between schools and parents, prompting the need for enhancements to ensure timely updates and reports. The goal of the project is to create a unified system that prioritizes edge processing optimization in order to bridge these gaps. The objective is to facilitate prompt analysis, guaranteeing a seamless experience for educational and professional establishments, and concurrently tackle current obstacles in the implementation of existing systems in Rwandan schools.

CHAPTER III: RESEARCH METHODOLOGY

3.1. Introduction

The Research Methodology chapter serves as a blueprint toward the implementation of the student behavior monitoring system. This section introduces the rationale behind the chosen methods and their alignment with the research objectives already outlined in the abstract.

3.2. Research Design

By using computer vision and IoT technologies. The technology simplifies the administration of punishment, analyzes behavioral trends, and automates attendance tracking. It guarantees precise and safe attendance records by leveraging edge processing and computer vision technology. Autonomously very month, behavior reports are produced, and in the event of a student's absence, parents are promptly contacted via normal SMS.

The application combines machine learning frameworks and edge processing algorithms for thorough behavior analysis, and the ESP32 CAM is used to provide video streaming and picture taking. Additionally, the system has sophisticated capabilities that allow for the remote monitoring of classroom activities, the quick detection and recording of anomalous conduct, and the immediate notification to authorized personnel.

3.2.1. Engineering Design process

A number of procedures are included in the Engineering Design Process as shown in fig.1 with the goal of solving real life challenges in an efficient manner. In order to address the challenge of "Students' Behavior Monitoring using IoT and Computer Vision in Rwandan Schools," the research, in conjunction with its practical implementation, diligently applied the Engineering Design Process. This methodically guided the creation of efficient solutions catered to the particular context and requirements of the educational atmosphere.

The following is a sequence of Engineering Design Processes used to generate workable answers to issues depicted in the research challenges.

1. Ask (Awareness of the Problem)

- Identify the problem: the first Step is to understand the challenges associated with monitoring student behavior in Rwandan schools.

- Definitions of constraints: Consider limitations such as resource availability, technology infrastructure, and cultural considerations.

- Context comprehension: Explore the educational environment in Rwandan schools, considering cultural nuances and specific requirements.

2. Imagine (Brainstorming of Solutions)

- Conduct brainstorming sessions: Engage in creative thinking to generate potential solutions.

- Ideation: Explore diverse possibilities and relevance for implementing behavior monitoring using IoT and computer vision.

- Encourage creativity: Allow for the generation of innovative ideas without immediate concern for feasibility.

3. Plan (Gather Needed Materials)

- Selection of a promising concept: Choose a solution that aligns with the unique needs of Rwandan schools.

- Develop a detailed plan: Outline steps for implementation, considering the integration of IoT and computer vision.

- Gather necessary materials: Identify the required hardware, software, and other resources.

4. Create (Follow Plan and Test It Out):

- Assemble components: Follow the established plan to integrate IoT and computer vision technologies.

- Construct the system: Implement the solution in a real-world setting within Rwandan schools.

- Build prototypes: Develop prototypes to test the functionality of the behavior monitoring system.

5. Improve (Discuss What Can Work Better)

- Test and evaluate: Assess the performance of the behavior monitoring system in real-world conditions.

- Gather feedback: Collect input from students, teachers, and other stakeholders.

- Identify areas for enhancement: Analyze test results and engage in discussions to refine and optimize the design.

- Undertake iterative cycles: Implement improvements based on feedback and testing results.

The Engineering Design Process is iterative, and feedback from each phase informs decisions in subsequent stages. This systematic approach ensures that the behavior monitoring system continually evolves to meet the specific challenges and requirements of Rwandan schools.

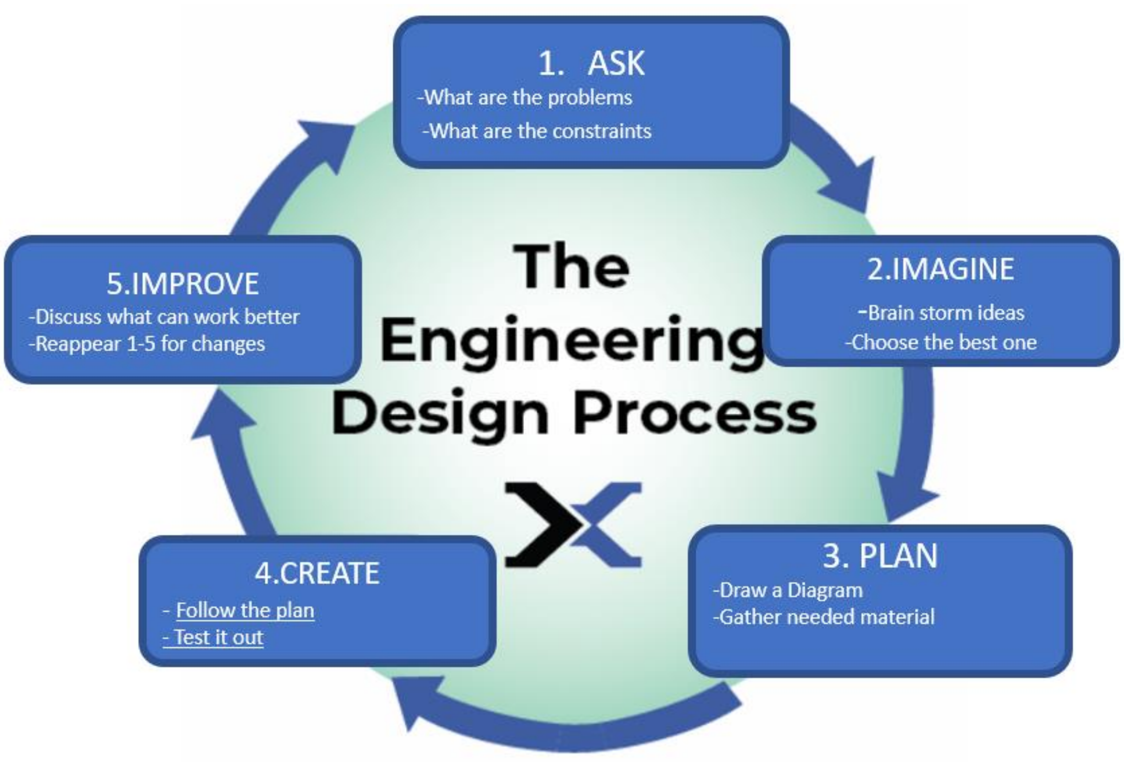


Figure 1 : Engineering design process

3.3 Overview of IoT-based behavior monitoring system

The operating principle of the system involves the following components and their interactions:

1. ESP32-CAM and Android Camera: These parts are essential for taking pictures that are prompted by an SMS instruction from staff members who are located at a remote or by a Wi-Fi signal from the Android device. Once they're turned on, they take pictures and quickly upload them to Google Drive for safekeeping. These gadgets also perform well as video streaming devices, which makes remote video control capabilities very possible.

1. **Android Device:** The Android gadget performs several functions within the framework. It establishes a wireless network to which the Android app and the ESP32-CAM can connect. By delivering notifications to parents and authorized professionals, it serves as an SMS gateway. Additionally, it gets SMS commands for remote control from approved workers. The Android application that is installed on the device can process the Android video feeds.

3**. Communication**: The ESP32-CAM and the Android device communicate via Wi-Fi for triggering picture capture. The Android device communicates with the ESP32-CAM and the Android app using a Wi-Fi network it creates. SMS messages are exchanged between the Android device and authorized personnel for remote control commands and real time notifications. Additionally, the Android app sends emails on a monthly basis to parents, containing attendance reports from its database.

4. Google Drive: To store collected images, the ESP32-CAM and Android smartphone move them to Google Drive. They upload the photos by using the Android device's internet access.

5. TensorFlow: To process the video streams, the Android app on the Android device explores TensorFlow computer vision algorithm incorporated. It recognizes and finds items in the live feed.

FaceNet: Capturing images and doing facial recognition for attendance verification is the main use of the FaceNet API, which is easily integrated into an Android app. After that, the attendance records are kept in local storage and made available to authorized staff upon request or automatically on monthly basis.

3.4 Realtime face recognition with Android + TensorFlow Lite

To integrate deep learning models into mobile applications with ease, there are a number of clearly defined processes involved in real-time face recognition on Android with TensorFlow Lite. TensorFlow Lite is first installed in the Android development environment, and a pre-trained face recognition model that is compatible with the framework is obtained. FaceNet models were used for face identification. The Android project then effortlessly included this concept. Preprocessing, inference, and camera integration are covered in the next steps.

The Android Camera API is used to access the camera, and frames from the stream are processed to match the input requirements of the model. TensorFlow Lite is used to carry out the inference process, which retrieve bounding boxes around recognized faces and facial landmarks. Upon completion of the inference process, the detected faces are refined and filtered using post-processing techniques like non-maximum suppression. In case of face recognition, further models or algorithms possibly requiring comparisons with a database of recognized faces are employed to identify specific people based on the recognized faces.

The outcomes, which include identified people or faces that have been matched, are then shown in real time on the Android smartphone and are easily incorporated into the user interface. The stages that follow focus on privacy concerns, security, speed optimization, and iterative testing to guarantee correctness and robustness under many circumstances. Subsequent iterations are based on end user feedback and settings.

3.4.1 TensorFlow flow for image recognition

The TensorFlow flow for image recognition, specifically for face image processing fig 2., involves a detailed sequence of steps that leverage various components of the TensorFlow framework. This process is crucial for achieving accurate face detection and recognition.

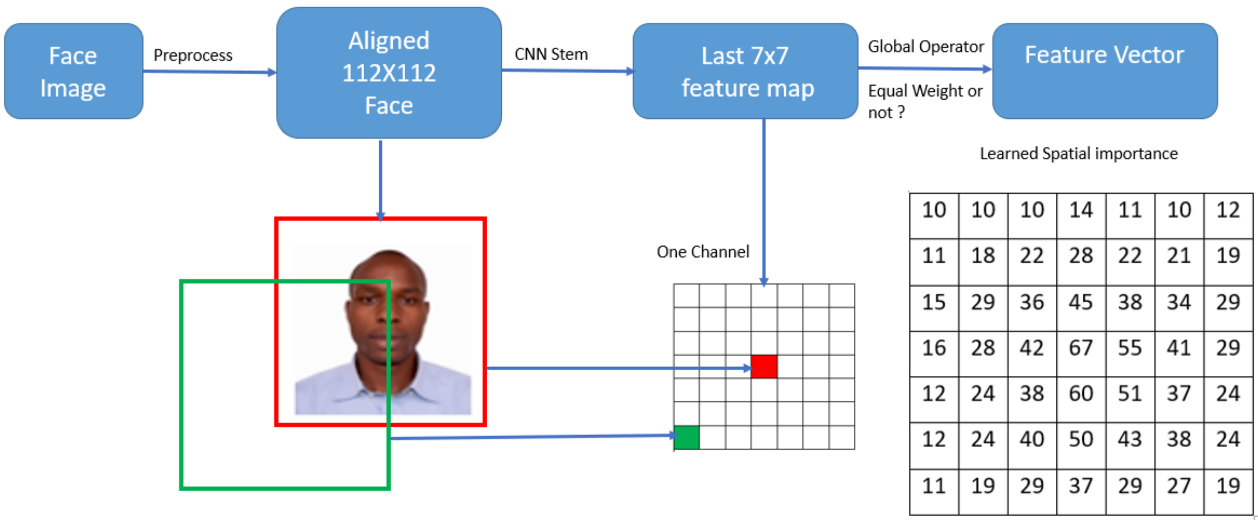


Figure 2: TensorFlow flow for image recognition

1. Face Image Preprocessing:

- Initially, face images undergo preprocessing, encompassing tasks like resizing, normalization, and other potential transformations. TensorFlow's image processing functions and utilities are employed to ensure the input images align with the specific requirements of subsequent model layers [13] [14].

2. Aligned CNN Stem

- A successful preprocessed face images are then fed into a Convolutional Neural Network (CNN) stem. The stem serves as the initial layer of the neural network, responsible for extracting basic features from the input data. TensorFlow's high-level APIs, like Keras or the lower-level API, facilitate the construction and training of the CNN stem [15], allowing developers to define and configure various convolutional and pooling layers.

3. Last 7x7 Feature Map

A series of feature maps are produced when the facial picture moves through the CNN's layers. The final 7x7 feature map is a simplified depiction of the key characteristics that were taken out of the original picture. [16] This final feature map is the result of TensorFlow's efficient operations for spatial reductions using pooling layers.

4. Global Operator

- The global operator is applied to the last 7x7 feature map, typically in the form of global average pooling. TensorFlow's pooling operations are instrumental in this step, favorizing the computation of the average value of each feature across the spatial dimensions. This operation helps distill the most salient features and reduce the spatial resolution.

5. Equal Weight or Not Feature Vector

- Finally Creating a feature vector from the global operator's output is the last stage. TensorFlow's operations allow developers to apply weightings based on the significance of individual characteristics or to assign equal weights to each feature, depending on the requirements of the face recognition model. This adaptability enables customization and improvement to boost the feature vector's discriminating ability.

TensorFlow serves as a powerful tool throughout this process, offering a versatile platform for building and training neural networks, performing image processing tasks, and implementing intricate operations crucial for effective face detection and recognition. We can seamlessly leverage TensorFlow's functionalities to create robust and efficient models for image recognition, including those tailored for face recognition applications.

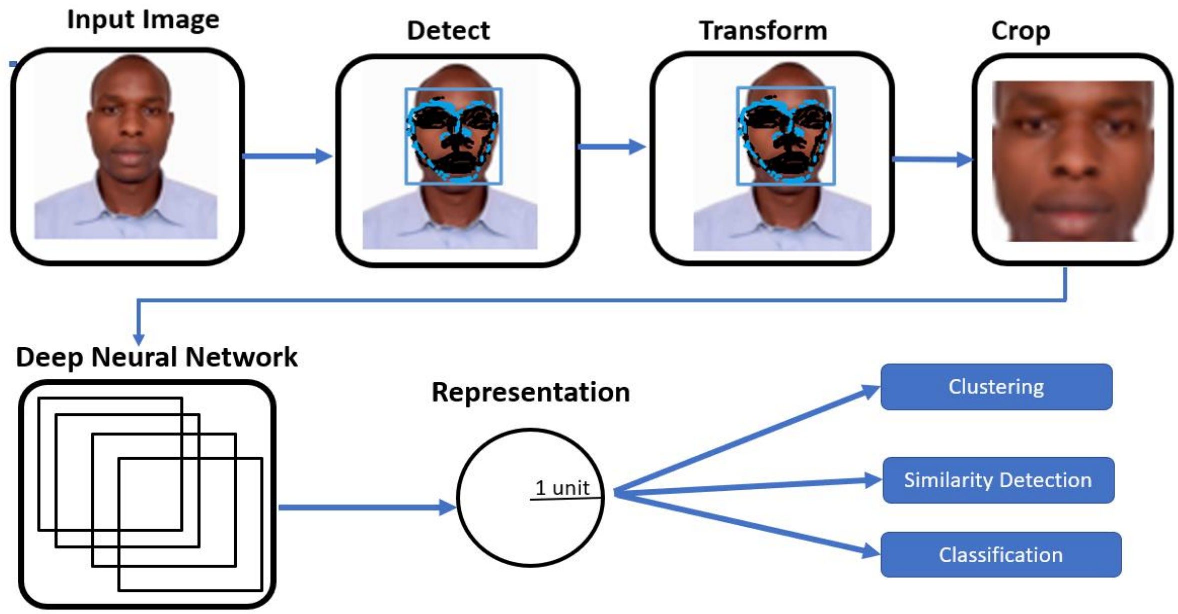


Figure 3: Pipeline of a facial recognition system

First, the system recognizes the face in the input image during the first stage. After that, the picture is warped by mean of the recognized facial landmarks to properly align the face [17]. The eyes in every cut face are positioned consistently many thanks to this alignment. The face is suitably scaled and cropped in the third phase before being fed into the Deep Learning model for recognition as demonstrated if figure 3. During this phase, a number of other picture pre-processing procedures are also taking place, including "whitening" and normalization of the facial characteristics. Lastly, the critical phase, in which we call the "Deep Neural Network," assumes a central role in our utmost procedure. The significance of this section in the system as a whole justifies further attention to it.

$$Similarity\ (F1, F2) = ||DNN(F1) - DNN(F2)||2 = \sqrt{\sum_{i=1}^{D}(E1i - E2i)\,2} \qquad \text{i)}$$

Equation 1: Similarity between faces can be computed as the Euclidean distance between its imbedding

The core concept revolves around the deep neural network, denoted as DNN, which accept a facial image F as input and produces a 128-dimensional vector D (composed of floats) as output. This vector, termed embeddings and represented by E, serves as a distinctive numerical representation. These embeddings are crafted in a manner that allows the comparison of facial similarities. Specifically, the similarity between two faces, F1 and F2, can be effortlessly calculated as shown in equation i) by determining the Euclidean distance between their respective embeddings, E1 and E2 the equation 1. shows how Similarity between faces can be computed as the Euclidean distance between its imbedding

Practically we use a deep learning framework TensorFlow. Below is a snipped snippet that demonstrates the concept used in our model.

```java
import org.tensorflow.Graph;
import org.tensorflow.Session;
import org.tensorflow.Tensor;
import org.tensorflow.TensorFlow;

public class FaceSimilarityIdentifier {
  public static void main (String[] args) {
    // Load the TensorFlow library
    try {
      System.loadLibrary(TensorFlow.NATIVE_LIBRARY);
    } catch (UnsatisfiedLinkError e) {
      System.err.println("TensorFlow library not loaded");
      System. Exit(1);
    }

    // Create a TensorFlow graph
    try (Graph graph = new Graph()) {
      Graph.Operation inputOperation = graph.opBuilder("Placeholder", "InputImage")
        .setAttr("dtype", org.tensorflow.DataType.UINT8)
        .build();

      // Placeholder for output embeddings
      Graph.Operation outputOperation = graph.opBuilder("Placeholder",
"OutputEmbeddings")
        .setAttr("dtype", org.tensorflow.DataType.FLOAT).build();

      // Calculate Euclidean distance between embeddings E1 and E2
      Graph.Operation euclideanDistanceOperation =
graph.opBuilder("EuclideanDistance", "EuclideanDistance")
        .addInput(outputOperation.output(0))
        .addInput(outputOperation.output(1)).build();

      // Create a TensorFlow session
      try (Session session = new Session(graph)) {

        float [] embedding1 = {/  E1 values  / };
        float [] embedding2 = { /  E2 values  / };
      /  In a practical scenario, one embedding is generated in real-time from a
camera stream, while the other is derived from an already stored local database.  /
        Tensor<org.tensorflow.DataType.FLOAT> embeddingsTensor1 =
Tensor.create(embedding1, org.tensorflow.DataType.FLOAT);
        Tensor<org.tensorflow.DataType.FLOAT> embeddingsTensor2 =
Tensor.create(embedding2, org.tensorflow.DataType.FLOAT);

        // Perform face similarity calculation using Euclidean distance
        float euclideanDistance = session.runner()
          .feed(outputOperation.output(0), embeddingsTensor1)
          .feed(outputOperation.output(1), embeddingsTensor2)
          .fetch(euclideanDistanceOperation.output(0))
          .run()
          .get(0)
          .expect(Float.class)
          .floatValue();

    System.out.println("Euclidean Distance between faces: " + euclideanDistance);
      }
    }
  }
}
```

3.3.1 System Architecture

To monitor and control a classroom activity, the system is made up of an Android phone, an ESP32-CAM, and a software and software equipped with broadcast capabilities, Android uses a combination of system services, Broadcast Receivers, and permissions to receive and detect signals such as Bluetooth, GSM calls, SMS, and Wi-Fi this will enable the system to accurately implement remote control capability even without relying on internet connectivity. With its built-in camera module, the ESP32-CAM is in charge of taking pictures. The collected images are uploaded to Google Drive as soon as it detects Wi-Fi signals from the Android device. The ESP32-CAM's video stream is processed remotely, giving administrators a viable remote access to the class's status. In addition, the Android device creates a Wi-Fi network, serving as a hub that links authorized personnel, the Android app, and the ESP32-CAM. The figure 4 shows Integrated Control and Monitoring Layers for Classroom Management System Framework.

Authorized staff can remotely adjust the classroom setting by sending SMS commands to the Android app which in turn will automatically adjust the settings accordingly. Activating real-time audio notifications and requesting real-time behavioral reports are two practical examples of these instructions. The activities in the classroom can be observed by authorized personnel, who can also be notified through alerts if the system autonomously notice any strange conduct.

Effective parent-teacher communication is another feature of the system. Parents receive real time notification via SMS on their child's attendance as well as information about compliance with school policies. In case of unusual behavior, the Android app promptly notifies authorized personnel via SMS. This this autonomous check enables them to address the issues promptly, providing necessary support to prevent any escalation of associated consequences.

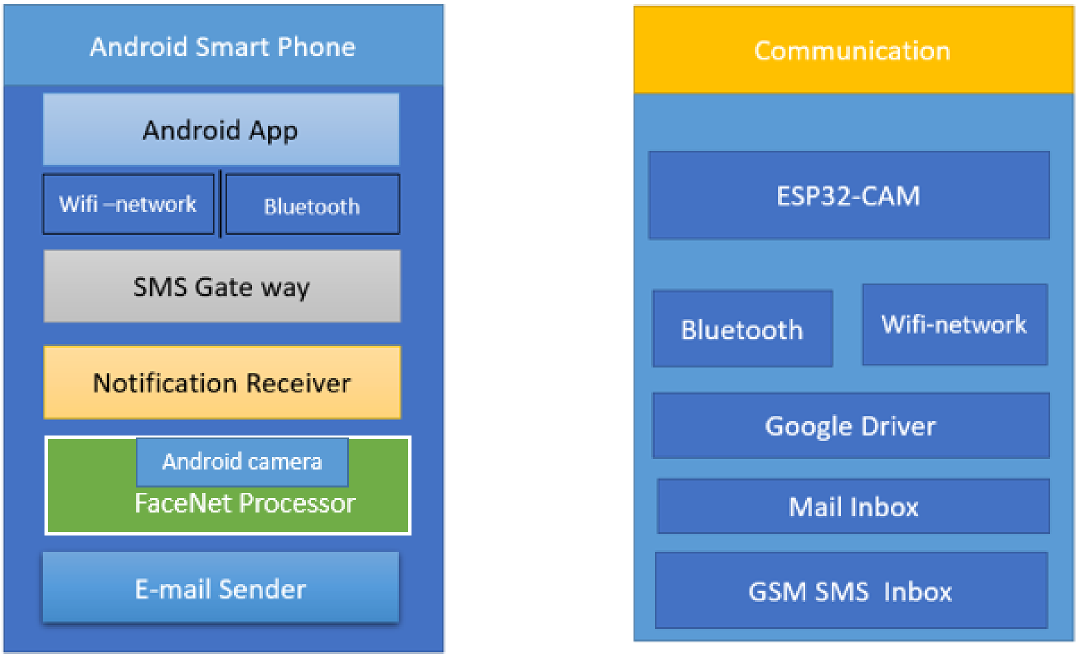


Figure 4: layers of abstraction within the system

The figure 5. below shows the block diagram that serves as a visual representation that offers a comprehensive overview of the system architecture, delineating the intricate relationships and interactions between various components integral to the system's implementation. Through the use of blocks, each representing distinct system components, and connecting lines that signify the flow of information or control, the diagram elucidates the organizational structure and functional connections within the system

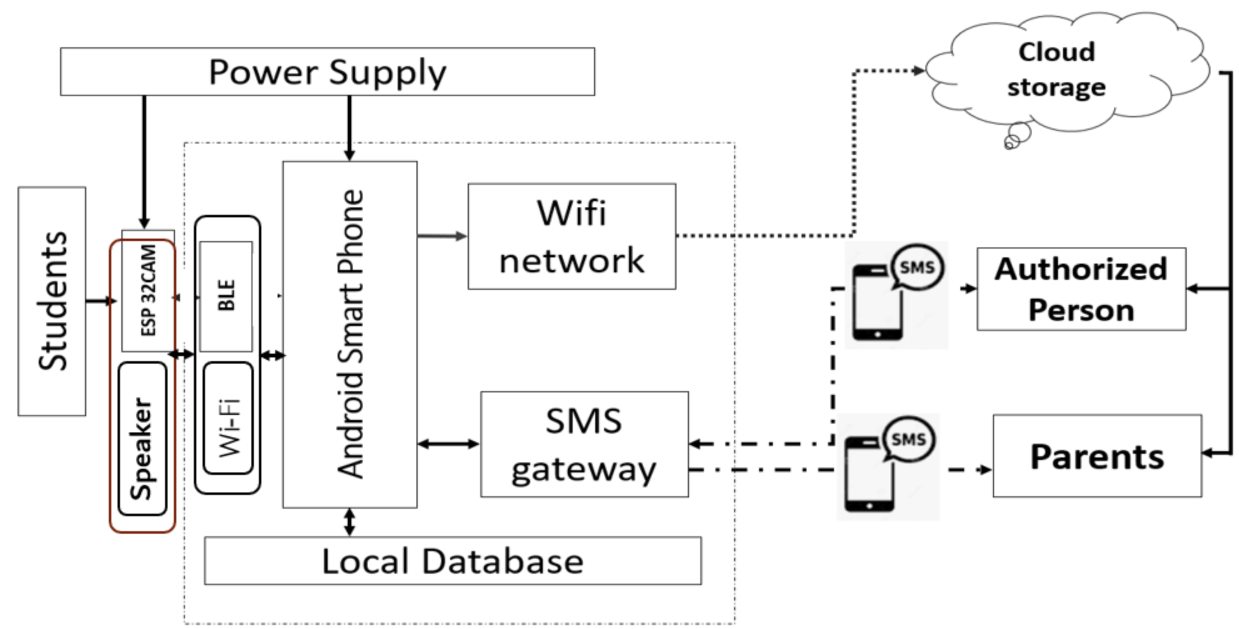


Figure 5: System block diagram

CHAPTER IV: SYSTEM ANALYSIS AND DESIGN

4.1 Introduction

This chapter presents a thorough investigation into the many components and approach used for student behavior monitoring system that aims to transform teaching methods in Rwandan schools. With a deep emphasis on the analysis and design of the system, this chapter carefully lays out a theoretical framework and combines it with real models and simulations to guarantee the smooth and effective functioning of the implemented system. The following theoretical framework provides the intellectual foundation and justification for the selection and integration of these technologies. It is based on the combination of Edge processing, Internet of Things (IoT) and computer vision technologies.

This part lays out the theoretical framework that will be the base for later stages of implementation, ensuring a solid base. Beyond theory, this chapter follows carefully thought-out models and simulations that serve as schematics for the architecture, processes, and relationships inside the system. Before implementing a solution in the real world, simulations illustrated in this chapter provides a virtual testing ground for potential issues to be identified and resolved. This thorough study and design stage prepared the reader for the upcoming chapters, which reveal the system's characteristics, functionality, and revolutionary effect on Rwandan schools' educational environment.

4.2. Theoretical Framework

This thesis' theoretical framework centers on the development of a student behavior monitoring system for Rwandan schools through the combination of computer vision and Internet of Things (IoT) technologies. The system's objectives are to improve disciplinary management, study behavioral trends, and automate attendance monitoring. The ideas and concepts behind edge processing, computer vision and the Internet of Things—which are regarded as cutting-edge technologies for accomplishing the aforementioned goals—form the theoretical foundation using networked devices to provide real-time data sharing and communication known as IoT integration.

Concurrently, computer vision aids in the analysis of behavioral patterns via machine learning algorithms, allowing the system to identify odd behavior and improve safety in the educational setting this computation is done at the device level by using edge processing technology.

The intellectual core of the student behavior monitoring system is provided by this theoretical framework, which also serves to support the choice and integration of IoT and computer vision technologies for a vivid, solid and well-founded foundation.

4.3 Conceptual Model

The ESP32-CAM, Android phone, and related software modules are the three main components that interact dynamically in the conceptual architecture of the student behavior monitoring system. Fundamentally, the android camera, camera module-equipped ESP32-CAM serve as the main data collection devices that takes pictures of the Realtime activities taking place in the classroom. The method works on the fact that the ESP32-CAM automatically uploads the picture it takes to Google Drive as soon as it detects Wi-Fi signals from the Android phone. Administrators can simultaneously process the ESP32-CAM's video stream remotely, giving them real-time control over the classroom's operating status from a distance.

4.4 The working principle of the system

The student behavior monitoring system is initialized by both an Android device and an ESP32-CAM. The Android device sets up a Wi-Fi network, and the ESP32-CAM automatically connects to it. The system continuously waits for signals issued by relevant broadcasts, first Wi-Fi and then Bluetooth, from the Android device. Upon receiving Wi-Fi commands, the ESP32-CAM processes them until completion, and the same applies to Bluetooth signals. The ESP32-CAM captures a photo, uploading it to Google Drive. Communication occurs through the established Wi-Fi network, concurrently, the system awaits SMS commands from authorized personnel. If an SMS command is received, it is processed accordingly.

Additionally, the system uses computer vision techniques to process a video stream in order to detect and identify processable items in it. The attendance record is updated if a registered student appears in from of it; if not registered, an alert message for unregistered students is shown.

Periodically, the system verifies the daily and monthly deadlines, alerting the parents of absent students by SMS and providing a list of absentees to authorized staff upon completion of each attendance. A comprehensive attendance summary is supplied only to authorized individuals, and monthly attendance reports are routinely prepared and emailed to respective parents.

Furthermore, authorized people are also capable of remotely initiating any particular reporting activity by simply sending an SMS with corresponding command.

This cyclic monitoring and reporting process continues indefinitely. system demonstrates a robust capacity to operate autonomously and continuously, irrespective of internet connectivity or power outages although the system is connected to 220V socket outlet, it remains operational for hours . This resilience is facilitated by the Android device's built-in battery, ensuring uninterrupted functionality. The system relies on the Android device thanks to android broadcast receivers, additionally android device creates a Wi-Fi network for seamless communication with the ESP32-CAM. The incorporation of SMS notifications significantly boosts reliability since it is independent of internet access, and the cellular network possesses an extensive coverage area.

4.5 System PDL

The provided PDL (Program Design Language) outlines the system's operation for monitoring student behavior in academic setting using an Android device and ESP32-CAM. The system initializes both devices and establishes a Wi-Fi network connection between them. The system continuously waits for signals, including Wi-Fi signal and Bluetooth signals from the Android device and SMS commands from authorized personnel. Upon receiving commands either from local user or remote controller, it processes each one accordingly.

It utilizes the ESP32-CAM to capture photos, uploads them to Google Drive, employs computer vision algorithms and edge processing to analyze video streams, detecting and identifying processable objects. The system updates attendance records for registered member, issues alert for unregistered students, and sends SMS notifications to respective parents if a student is absent on daily basis, additionally a monthly report is distributed via email to parents and authorized personnel. The overall structure ensures autonomous and continuous monitoring and response to various signals and commands for effective behavior tracking in educational setting.

System PDL

BEGIN

Initialize Android Device and ESP32-CAM

Initialize variables

Create Wi-Fi network on Android handset

Connect ESP32-CAM to the Wi-Fi network

Initialize android camera

DOFOREVER

Wait for Wi-Fi signal from Android Device

Wait for Bluetooth signal from Android Device

Wait for SMS commands from authorized user

IF Wi-fi signal received

DO

Process Wi-Fi command the command

UNTIL Wi-Fi command received

ENDDO

ENDIF

IF Bluetooth data received

DO

Process Bluetooth data

UNTIL Bluetooth data Processed

ENDDO

ENDIF

Activate ESP32-CAM to capture a photo

Upload the captured photo to Google Drive

Establish communication between Devices and ESP32-CAM using Wi-Fi network

IF SMS command received

DO

Process the command

UNTIL SMS command received

Process video stream received using CV algorithm

```
        Detect and identify objects in the video stream
        IF Registered student detected
          DO
            Update the attendance record
          UNTIL Registered student detected
          ENDDO
        ENDIF
        IF Unregistered student detected
          DO
            Display an alert message: "You are not Unregistered"
          UNTIL Unregistered student detected
          ENDDO
        ENDIF
        Check daily deadline
        IF Absence is notified
          DO
            Send SMS notifications to parents and authorized user
          UNTIL Absence is notified
          ENDDO
        ENDIF
        Check monthly deadline
        Generate monthly attendance reports
        Send attendance reports to respective parent via email
        Send overall attendance report to authorized personnel
      ENDIF
    ENDDO
END
                ENDDO
           ENDIF
```

CHAPTER V: RESULTS AND ANALYSIS

The actual results of the student behavior monitoring system's implementation are presented in this chapter, it offers a thorough examination of the findings in term of behavioral analysis, parent communication, and attendance tracking. To illustrate how well the system meets its predetermined goals, a thorough examination of these findings is conducted.

Moreover, a comparative analysis is performed by contrasting the obtained outcomes with those of previous systems. Through informative combative tables, the chapter explains the system's unique innovations and distinctive features, emphasizing successful usage requirements and recommended practices for maximizing system efficiency. Furthermore, a range of other possibilities have been investigated in order to initiate ease of update relative to current systems, resulting in an extensive assessment of the system's functionality and unique contributions.

5.1 Face registration and recognition flow within the system

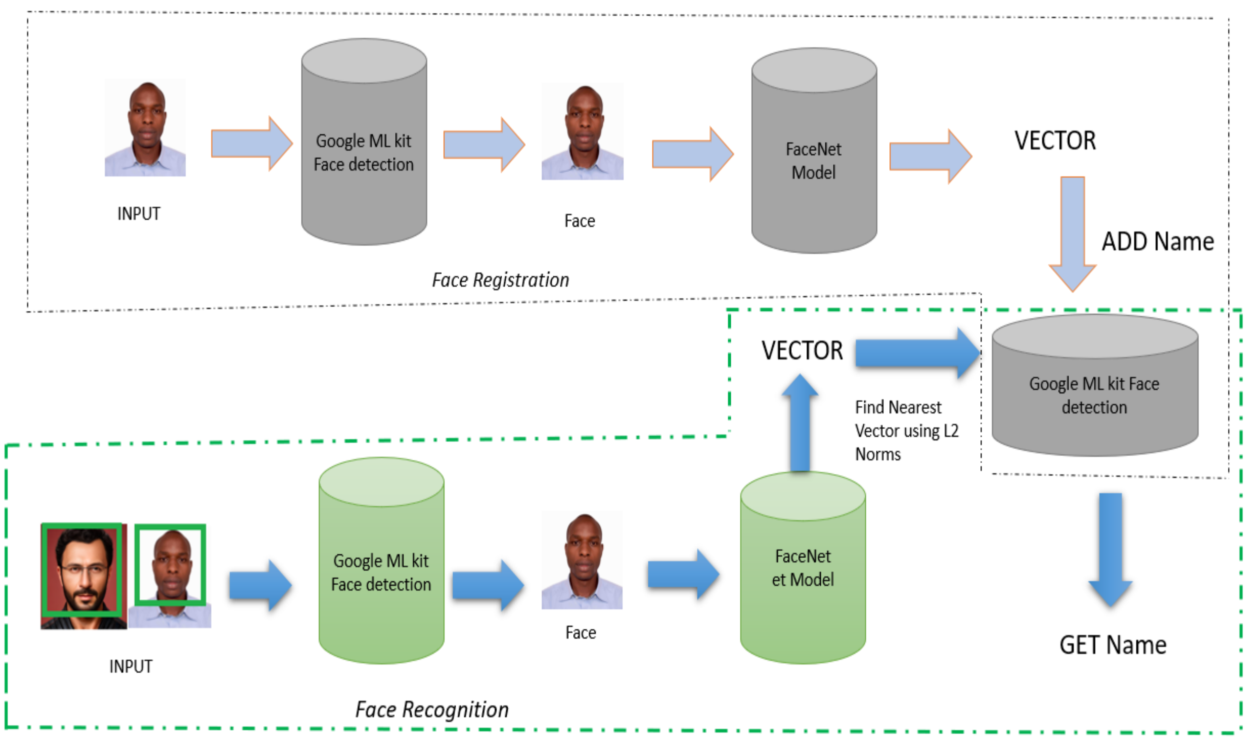


Figure 6: Face registration and recognition flow within the system

The figure 6. Depicts the face registration and recognition flow within an Android device this involves several important steps. Initially, an input image is fed to the system.

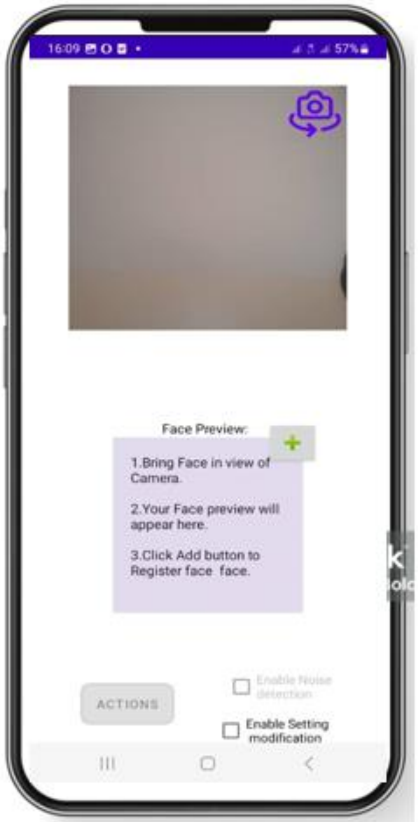
This image undergoes face detection using Google ML Kit, a powerful machine learning framework for mobile devices. Once the face is detected, the system utilizes the FaceNet model, as used state-of-the-art facial recognition model, to extract a facial vector representation from the input image.

This facial vector is then compared or matched against a pre-existing database of facial vectors already saved. The database stores vector representations of registered faces, allowing the system to identify and recognize individuals based on their unique facial features. If a match is found, the system recognizes the person as a registered user and attendance is recorded in case of attendance in progress or an option to register a new user is initiated in case of user registration.

5.1.1 Successful registration

In order for a new member's registration to be successfully performed, their face may be seen facing or facing the back camera, depending on the user's choice or picture source or personal preference. The image is transformed and cropped after it has been identified figure 7. The registrant must click the "+" button to add their face to the database and the picture embedding is permanently registered after verifying stability and clarity in the cropped image region figure 8.

It is important to remember that this verification stage is necessary, particularly since quicker and unfocused registrations could lead to a decrease in the accuracy of picture recognition. Therefore, adequate time for proper image detection is necessary. Additionally, it is advised that individuals not wear glasses during the face registration process to avoid any potential confusion in attendance records.



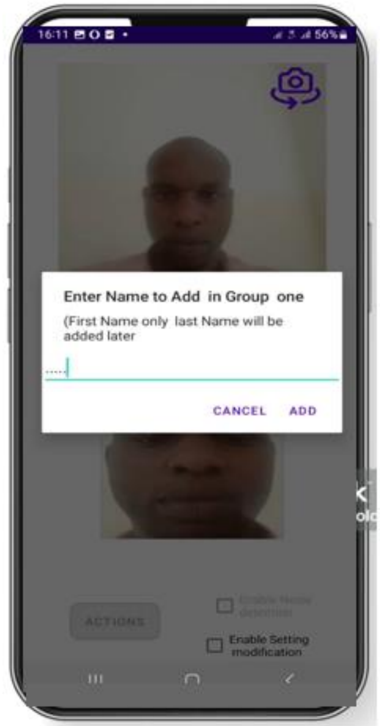


Figure 7: Face preview initialization

Figure 8: Face registration

5.1.2 Accuracy of Attendance Records

A Registered member only needs to present himself in front of the camera to register his attendance; the system will take care of the rest. This includes using facial recognition, time stamping the attendance record, and displaying alert message to inform the member that the recording is successful figure 9.

The system notifies a member who has previously documented his attendance figure 10. that no more action is required; a member cannot record his attendance again for an initiated attendance. Crucially, edge processing allows this process to successfully run offline, perform well without the need of a constant internet connectivity. The successful time stamped recording increases the trust in face recognition; nevertheless, if face identification and registration have been done carelessly during registration without respecting the detailed instructions, this may result in unknown members during attendance which cannot be recorded.

Figure 9: Interface for new attendance record registered

Figure 10: Feedback for already

5.2 IoT and Automation set up

5.2.1 Internet of Thing set Up

The user interface shown in figure 11. allows end-users to configure IoT settings for seamless system management. IoT settings encompass the following key parameters:

1. **Sender's Email Credentials:**

   Sender's Email Address: Specify the email address from which the system will send reports. This email address will be used to send reports to all members and comprehensive reports to authorized personnel.

   Email Password: Provide the password associated with the sender's email address for secure authentication.

2. **Sender's Phone Numbers:**

   Authorized Phone Numbers: Enter the phone number that is authorized to send commands to the system remotely. These authorized numbers will have the capability to command the system to perform specific actions. *Note: The subsequent sections will provide detailed information on the commands that can be remotely sent to the system.*

Instructions for IoT Settings:

Sender's Email Credentials:

Enter the valid email address and password associated with the sender's email. Ensure the provided email address has the capability to send emails to all members and comprehensive reports to authorized personnel.

Sender's Phone Numbers:

Specify the phone number that is authorized to send remote commands to the system.

This authorized number will have the privilege to remotely command the system for specific actions.

Next Steps:

After configuring IoT settings, proceed to the next sub-units especially automation setup for a detailed explanation of the commands that can be sent remotely to the system. This refined description aims to clearly communicate the purpose of each IoT setting and guide users on how to provide the necessary information for effective system management.

5.2.2 Automation Set Up

End users can easily customize attendance settings in the automated setup shown in Figure 11 to suit their own requirements. You can also add exception dates when attendance will be automatically disabled, set precise start and stop times for particular attendance periods, and turn on or off SMS messages for absent members. You can also enable or disable attendance tracking. It's crucial to remember that the automated settings are made to run on a regular basis, guaranteeing that the parameters will repeat at certain times.

Key Features of Automation Setup:

1. **Enable/Disable Attendance:**

Functionality: Allows end-users to activate or deactivate attendance tracking based on their operational requirements.

Use Case: Useful when attendance tracking needs to be temporarily suspended or resumed.

2. **Exception Dates:**

Functionality: Permits users to specify exception dates during which attendance tracking will be automatically disabled.

Use Case: Ideal for holidays, special events, or any designated days when attendance tracking is not applicable.

3. **Start and End Times for Specific Attendance:**

Functionality: Enables users to set precise start and end times for specific attendance periods.

Use Case: Useful for organizations with flexible working hours or for capturing attendance during specific shifts.

4. **SMS Notifications for Absent Members:**

Functionality: Provides the option to enable or disable SMS notifications for absent members.

Use Case: Effective for keeping absent members informed about their attendance status through timely SMS alerts.

Automation Periodicity:

The configured automation settings operate on a periodic basis. The defined parameters, including attendance enable/disable, exception dates, start/end times, and SMS notifications, will recur based on the specified time intervals.

Usage Guidelines:

Users can review and adjust automation settings periodically to align with changing organizational needs. Configure exception dates in advance to account for holidays or special occasions. Specify accurate start and end times to precisely capture attendance during specific periods. Leverage SMS notifications selectively to keep absent members informed and engaged. This automation setup empowers end-users with a comprehensive and dynamic toolset, allowing for fine-tuned control over attendance tracking while ensuring adaptability to evolving operational requirements.

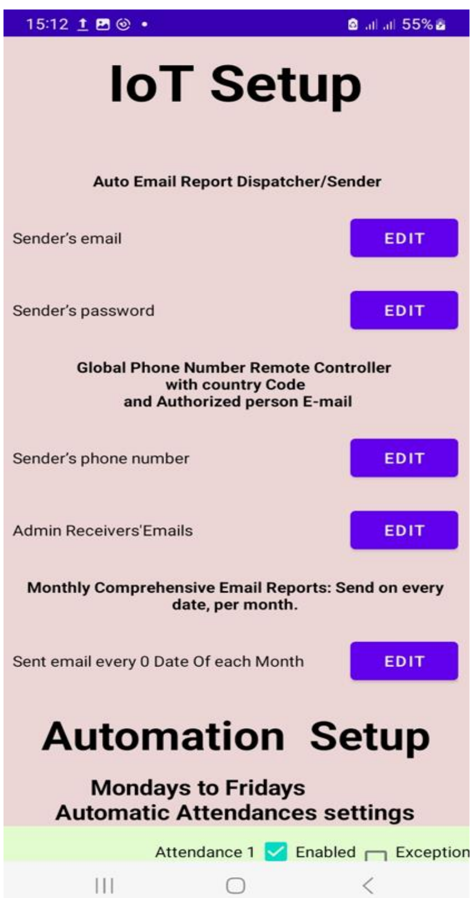


Figure 11 IoT set up

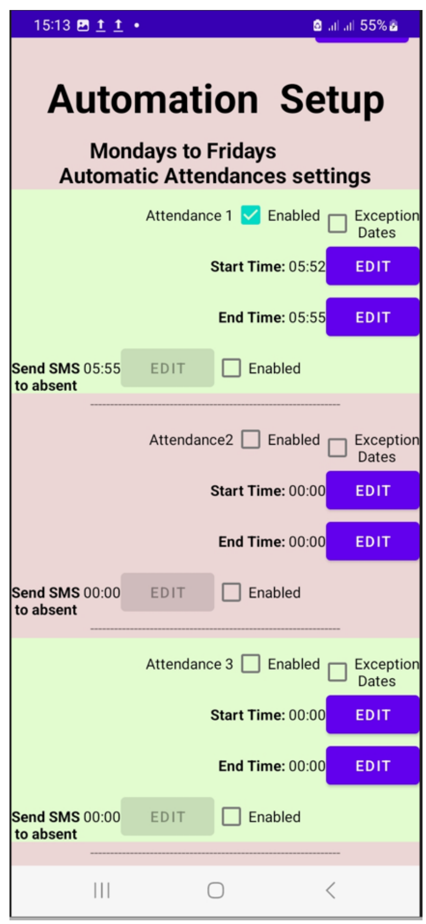


Figure 12: Automation Set Up

5.3 Attendance Reporting

The attendance reporting system has been designed to operate seamlessly on both a daily and monthly basis, employing SMS notifications specifically targeting absentees. For regular students, a comprehensive monthly report in Pdf format is generated and sent to the respective parents or guardians via email. To uphold privacy standards, each parent only receives the attendance report of his own child, ensuring confidentiality.

On a daily basis, the administrative team or authorized personnel promptly receive a summary report of absenteeism through SMS. This proactive approach ensures timely alerts are delivered to the concerned parents before any further communication. The streamlined process enhances communication efficiency and keeps parents well-informed about their child's daily attendance status.

For the reinforcement of data security and protection of privacy for each student, the attendance report is organized in such a way that only the relevant information for each student is disclosed. This not only complies with privacy regulations but also instills confidence in parents regarding the confidentiality of their child's attendance data.

This holistic approach aims to foster effective communication and ensure that parents are automatically well-informed about their child's attendance while upholding the highest standards of data security and privacy.

Users are given a smooth experience when accessing PDF attendance records in the user interface that is shown in figure . With this flexible system, users can send precise SMS commands to the system to generate reports remotely, automatically based on pre-set dates or schedules, or manually by clicking a dedicated button and confidentially share the Pdf report. A wide range of user preferences and operating scenarios are supported by the design of the user interface.

Key Features of the PDF Attendance Report Generation Interface:

1. **Manual Report Generation:**

Initiation Method: Users can effortlessly generate a PDF attendance report by manually pressing a designated button on the interface.

Use Case: Ideal for on-the-spot reporting needs or instances where immediate access to the attendance report is essential.

2. **Automatic Report Generation:**

Scheduling Options: The system supports automatic PDF report generation on preset dates or schedules.

Use Case: Suitable for recurring reporting requirements, as described a monthly report is streamlined for the reporting process

3. **Remote Initiation via SMS Commands:**

Remote Trigger: Authorized person have the capability to send specific SMS commands to the system, remotely initiating the issuance of a PDF attendance report.

Use Case: Valuable for scenarios where users need to access attendance reports remotely without direct access to the system interface.

Versatility in Report Retrieval:

Users can choose the most convenient method for obtaining PDF attendance reports, aligning with the operational needs. The flexibility accommodates diverse workflows, offering a tailored approach to report generation.

Usage Guidelines:

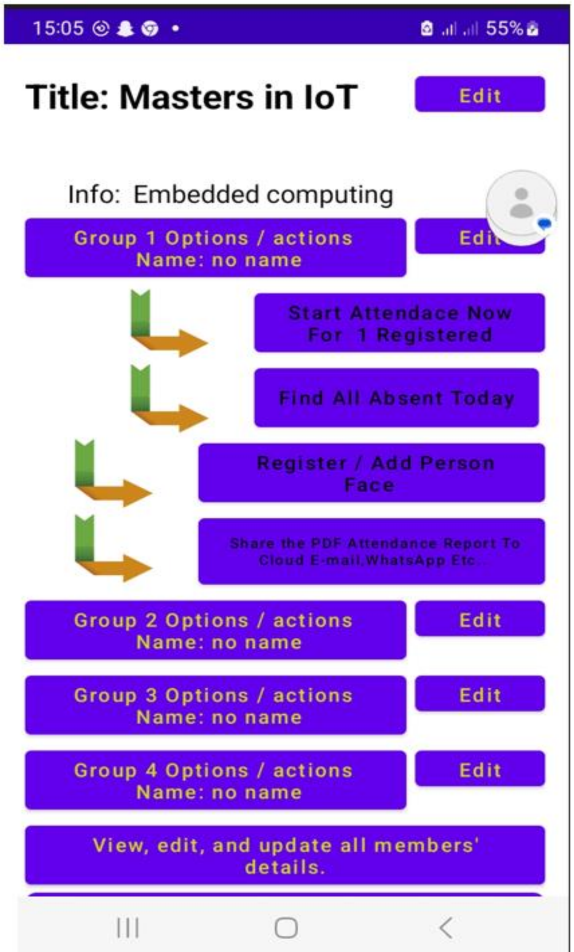
Manual Generation: Press the manual button when an immediate report is needed.

Automatic Generation: Set up preset dates or schedules for hands-free, periodic report generation.

Remote Initiation: Send SMS commands with specific instructions for remote, on-demand reporting.

Enhanced User Experience:

The user interface prioritizes user convenience, providing multiple avenues for accessing attendance reports. Remote initiation via SMS commands extends accessibility, allowing users to interact with the system remotely. This dynamic PDF attendance report generation interface ensures that users can effortlessly obtain attendance insights, catering to their preferred workflow—whether it's immediate, scheduled, or remote.



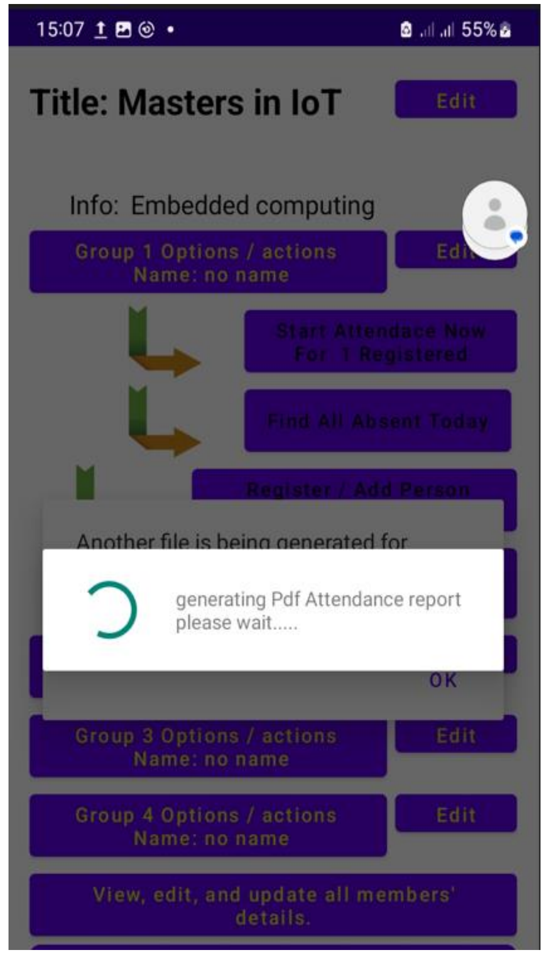


Figure 13: Manual attendance Reporting **Figure 14: Pdf Attendance report generation**

5.4 Remote control

With a dedicated link that is connected to the ESP32-Cam, the remote-control options provide users with flexible control capabilities, including the ability to stream live content and manage class remotely. Using this full remote-control feature, authorized staff can send commands to the system via SMS. These instructions cover a variety of tasks, such taking pictures of the current class state and sending them straight to Google Drive for storage.

To make sure that parents receive critical information on time, the system also permits the forced commencement of email reporting. Through the remote-control interface, staff can also obtain a daily summary report for absentee. In addition, the system makes it possible to send out bulk SMS messages to all parents to effectively informing them any public information.

Further innovative feature includes the ability to remotely record audio during class activities, enhancing the overall monitoring capabilities of the system. This integration of various controls not only streamlines administrative processes but also provides a comprehensive and user-friendly experience for authorized personnel oversee class-related activities.

Additionally, the system has a sophisticated feature that allows it to identify unusually and abnormal noise levels. When there a such noise, the system immediately calls in approved staff so they can keep an eye on the class activities remotely in case anything unusual happens. By adding an extra degree of security, the system performs better overall and can monitor and react to unforeseen events in a proactive manner.

End users have access to a wide range of remote-control commands within the system, which provide a variety of functions that can be started remotely. These commands are only meant to be delivered from approved phone numbers and are intended to set off particular system events. The list functions is extensive and includes a variety of tasks, such as taking pictures remotely and listening to real time audio.

The user experience is streamlined to ensure that end-users don't need to memorize complex codes; instead, they can effortlessly generate and share these remote commands with themselves for quick access.

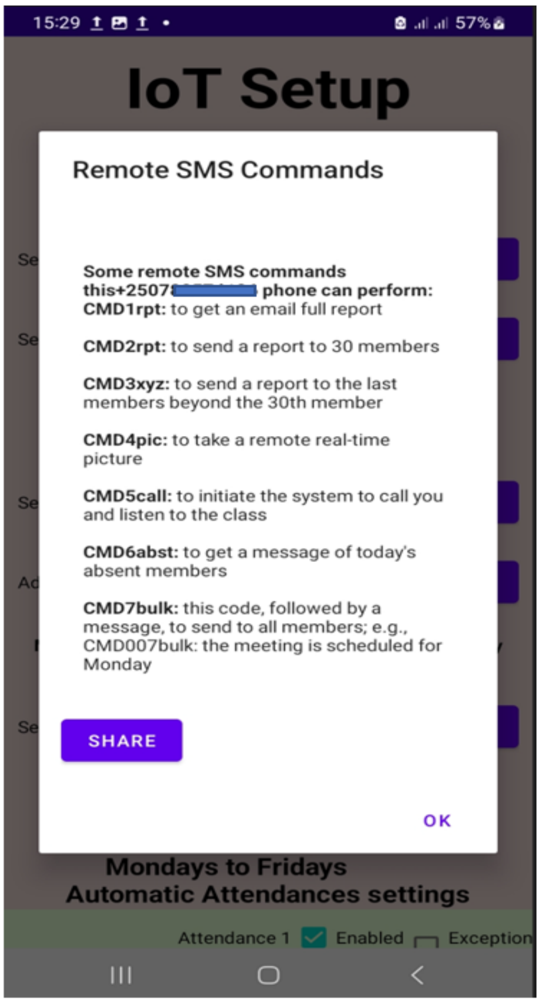


Figure 15: Remote SMS Commands

5.5 Miscellaneous options

A variety of other choices are included in the system to improve user customization. Users can optionally set up periodicals, control break timers, and automate student timetables with flexibility. The end user can choose how tasks and reminders are arranged for each activity by activating these settings according to their preferences. Then, to guarantee timely and efficient reminders, the system automatically creates alerts for every task and plays audible messages with text to speech engine.

Moreover, users have the option to enable music during break times, enhancing the overall atmosphere for students. This feature allows the system to play selected music during break timers, contributing to a more enjoyable and relaxing environment for students. By offering these customizable options, the system not only supports efficient task management but also strives to create an enjoyable, positive and personalized experience for end users.

5.6 Comparative Analysis of Technological Implementations in Student Behavior Monitoring Systems

In this analytical comparative table see table 1. we delve into the technological intricacies of developed and some of existing student behavior monitoring systems, shedding light on key aspects that define their functionality. The purpose of this table is to provide a concise and structured overview of the technological landscape within the designed system and three existing systems (A, B, and C).

Through an analysis in term of Internet of Things (IoT) deployment, computer vision technology use, machine learning algorithm application, and edge processing integration, we target to identify the unique technological strategies employed by each system. This comparison analysis provides a fundamental point of reference for a thorough comprehension of the technological foundations that contribute to the efficacy and distinctiveness of any student behavior monitoring system to favorize the relevant choice depending on end user requirement.

Table 1: Comparative Analysis of Technological Implementations in Student Behavior Monitoring Systems

Technology Aspect	Developed system (Student Behavior monitoring system)	Existing system A (Manual method student behavior monitoring)	Existing System B (Class Insight: A Student Monitoring System with Real-time Updates using Face Detection and Eye Tracking [18])	Existing System c Attendance Tracking Online: My Attendance Tracker[19]
IoT Implementation	Yes	No	Yes	No
Computer Vision Technology	Yes	Human Vision (require Human intervention)	Yes	No (Human visions and manual data entry)
Machine Learning Algorithms	Yes	No	Yes	No
Edge Processing capability	Yes	No	Yes	No
Automatic report	Yes	No	No	Manual reporting
Record storage	Locally and on cloud in digital form	Locally on hardcopy	On cloud (requires internet for access)	On cloud (requires internet)
Abnormality notification	Autonomously detected and reported	Detected by Human when present	Tracked by user while using the system	Initiated and tracked by admin after data analysis
Mean of remote communication	GSM technology (SMS and calls) and Internet connectivity.	No	Internet connectivity	Internet connectivity
Frequency of Dependence on Internet Connectivity	Once a month and on wish	No	Daily	Always
Subjection to bias	No available	Human error may bring bias	Minimized	Human error may bring bias

5.7 Communication effectiveness across various behavior monitoring systems

The Communication Effectiveness Table offers a structured comparison of important elements for evaluating communication effectiveness and communication infrastructure requirement across different behavior monitoring systems. Based on crucial communication aspects such real-time notifications, monthly behavior reports, frequency of updates, user accessibility, and ease of understanding, the following table assesses the currently designed and already existing systems (A, B, and C) depicted in table 2 . Every facet of communication is thoroughly investigated, including the methods used by the current systems and the suggested system.

Whether it's the instantaneous nature of real-time notifications, the format of monthly behavior reports, the frequency of updates, user accessibility methods, or the clarity of communication, this table serves as a summarized valuable tool for evaluating and contrasting the strengths and weaknesses of different behavior monitoring systems.

Table 2: communication effectiveness across various behavior monitoring systems

Communication Aspect	Developed system	Existing System A (Manual method student behavior monitoring)	Existing System B (A Student Monitoring System with Real-time Updates using Face Detection and Eye Tracking [18])	Existing System c Attendance Tracking Online: My Attendance Tracker [19]
Real-time Notifications	Instant delivery SMS notification	Manual observation	Web based notifications	Web based notifications
Monthly Behavior Reports	Emailed comprehensive reports with detailed insights	Hardcopies assembled	Notification reports generated on the web are accessible manually via either the website or a dedicated application.	Web-based notification reports are generated and can be accessed manually through either the website or dedicated application.
Frequency of Updates	Edge processing: Daily updates for timely information	Manual with Human intervention	Web based Daily update for timely information	Web based Daily update for timely information
User Accessibility	Parents access information through SMS and comprehensive reports via email.	Parent cannot access information regarding their child	Parent need to login to the platform to access comprehensive report	Parent need to login to the platform to access comprehensive report
Ease of Understanding	Clear and concise communication with straight forward language	Parents lack awareness of the actual events or occurrences affecting their children	Comprehension is greatly influenced by the user experience and a well-structured user interface.	Comprehension is greatly influenced by the user experience and a well-structured user interface
Scalability and possible use beyond academic setting	Automatically configures and customizable for specific domains like academic, professional, public institutions.	Human intervention always needed	Additional update and possible coding required to change the area of application	Additional update and possible coding required to change the area of application

In conclusion, the successful implementation of our student behavior monitoring system in Rwandan schools signifies a groundbreaking integration of IoT, computer vision, and machine learning technologies and edge processing. This innovative system has not only demonstrated exceptional results in automating attendance tracking but has also proven highly effective in behavioral analysis and discipline management especially in academic setting. Thanks to its sophisticated features, such as real-time SMS notifications, monthly behavior reports, and the capacity to identify unusual behaviors, the system has a potential to contribute significantly to improve communication channels between schools and parents. Additionally, it plays a crucial role in fostering a safer and more inclusive learning environment by providing educators with comprehensive insights into student behavior as whole or individual need.

Moreover, the system's distinctive attributes set it apart from other solutions as illustrated by comparative tables, offering a nuanced and advanced approach to behavior monitoring. Its ability to generate real-time SMS notifications ensures that parents stay informed promptly, fostering a collaborative relationship between schools and families. The monthly behavior reports provide a holistic view of student conduct, facilitating a more informed and proactive response from educators and possible parent involvement. It is worthwhile to mention that, the system's capability to detect unusual behaviors adds an extra layer of security and intervention, ensuring that potential issues are addressed promptly. In a comparative assessment, our system emerges as superior, showcasing its unique capabilities and innovations in the realm of student behavior monitoring in educational environment.

CHAPTER VI: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Utilizing IoT, computer vision, AI technologies and edge processing, the student behavior monitoring system designed show encouraging results in reaching the stated goals. The technology improves discipline management, analyzes behavioral trends, and automates attendance tracking. Secure data collection and analysis are ensured by utilizing computer vision and edge processing, and open contact with parents is promoted through real-time SMS notifications and monthly behavior disclosed reports. Behavior pattern analysis is made more sophisticated by the use of machine learning algorithms, especially when the ESP32 CAM is used to capture images. When combined with remote monitoring strategies incorporated for classroom activities, the system's capacity to identify and record anomalous conduct demonstrates a comprehensive approach to autonomously manage student behavior.

The study acknowledged inherent limitations, including data privacy concerns, required technological infrastructure, ethical considerations, and cultural/contextual factors. Despite these stated challenges, the research underscores the potential transformative impact of AI-driven analytics within a distributed edge computing architecture. The system's adaptability to evolving classroom dynamics, provision of personalized feedback, and creation of a more inclusive and enjoyable educational ecosystem are highlighted.

6.2 Recommendations

The education sector, as a whole, stands to gain substantially from the integration of AI technologies. AI-driven systems can assist educators in understanding and addressing the diverse needs of each students, thereby promoting more proactive teaching strategies. The student behavior monitoring system, in particular, aligns with the broader goals of creating safe, inclusive, and data-informed learning environments this state of art is recommend to each academic institution to excel its goals.

Education officials may make well-informed decisions, guiding curriculum development and putting into practice interventions that address the needs of specific students by utilizing insights from AI analytics. In order to fulfill the changing needs of contemporary education, partnerships between technology developers and the education sector can help to continuously improve and customize AI solutions. Teacher educating and Collaboration: Investigate how AI technology can be included into programs for educating teachers, promoting cooperation between instructors and AI systems to enhance instructional strategies.

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Annexes

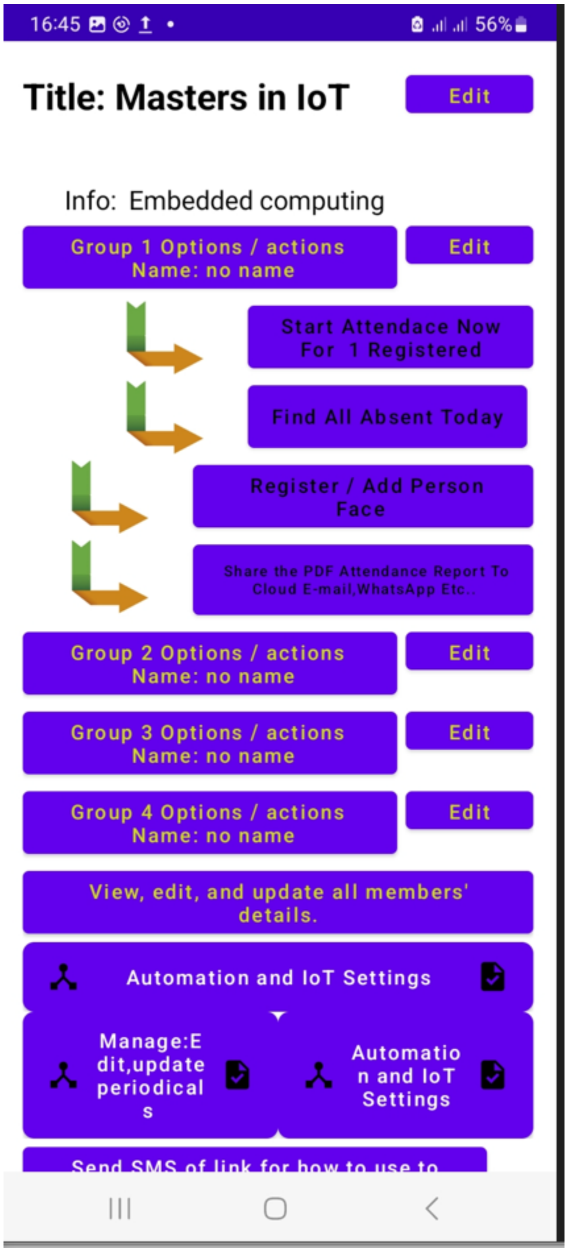

Figure 16: Main Dashboard

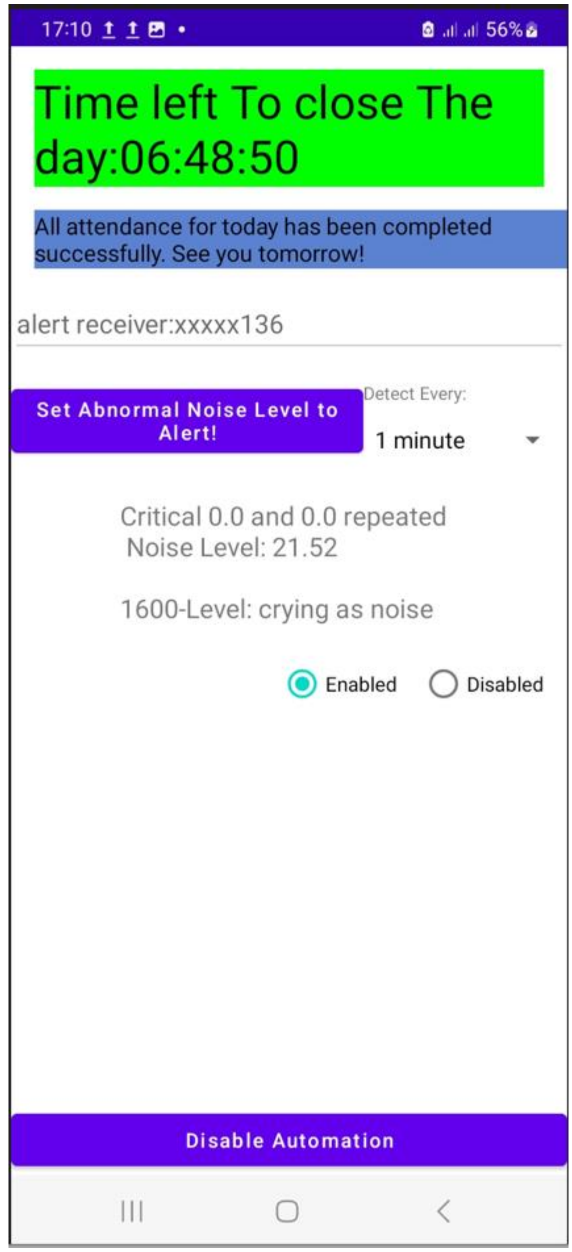

Figure 17:System Automation Interface