IoT based Smart Classroom System for Education Industry

ARUNMOZHI S. A., HARIEESHPALANI P. K., MUHILAN S., PARTHIBAN B.
Department of Electronics and Communication Engineering,
Saranathan College of Engineering,
Tamil Nadu,
INDIA

Abstract: Internet of Things (IoT) conceptualizes the idea of remotely connecting and monitoring real world objects through the Internet. When it comes to our class rooms, this concept can be aptly incorporated to make it smarter, safer and automated. Smart classroom is the main component of the contemporary education. Recognizing the importance of differentiated teaching modalities, integrating Information and Communication Technology has transformed traditional classrooms into intelligent learning spaces. With the emergence of current technology, it becomes comfortable for the students as well as teachers to carry out their tasks more professionally. With the aid of modern technology, it has become easier for the students and teachers across the world to get a good grasp of the theoretical as well as practical knowledge. This work focuses on building a smart classroom system. In this work, we present such a system where classroom hold interactions is made easier by implementing automation and security along with the IoT. The main goal of this work is to provide an efficient learning environment. The smart classroom model can be incorporated with PIC microcontroller and LCD display. This model will bring the automation in the attendance, doors will automatically open/close and finally the lights and fans in the classroom are started to operate automatically, when the student enter into the classrooms.

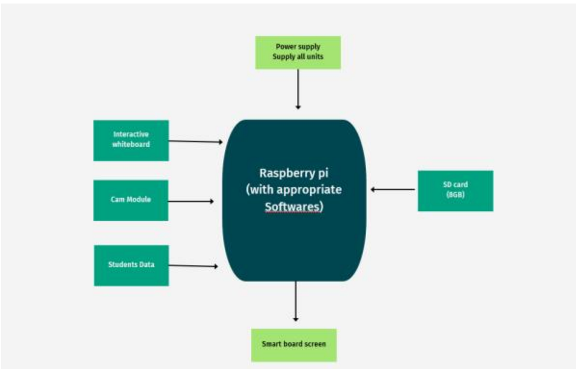
Key-words: Internet of Things, smart classroom, Cloud, Raspberry pi, Chatbot

Received: May 9, 2024. Revised: November 24, 2024. Accepted: February 2, 2025. Published: March 21, 2025.

1. Introduction

The classroom environment is a comprehensive indoor system encompassing various elements such as layout, design, infrastructure, and environmental factors like lighting, temperature and air quality. In today's competitive educational landscape, ensuring quality education is imperative, and technology plays a pivotal role in this regard. Intuitive classrooms, a progressive approach in the Indian education sector, aim to enhance teaching and learning experiences by fostering deeper engagement and better knowledge acquisition. The smart classrooms [1-11] leverage digital resources, interactive modules and instructional videos to enhance student performance and facilitate personalized learning experiences. By providing timely feedback, study aids, and support tools, smart classrooms empower students to learn anytime, anywhere, and in the most effective manner. The block diagram of the proposed work is given in Fig.1.

Fig. 1: Block diagram of the Proposed work



2. Methodology

Smart Classroom can be defined as the classroom equipped with the technology to aid teaching and learning. It is well known that from entering the classroom to leaving, the teacher is occupied in many of secondary nature jobs such as taking the attendance which eats up much of the time and after that adjusting the lighting of the room etc. Thus, teacher is left with a portion of allotted time which in much of the cases is not sufficed. With the help of smart classroom, it would be easier for a teacher to focus on primary job whereas the secondary job can be done in miniscule part of allocated time. It makes it possible to control the lights and fans automatically, the classroom doors are opened & closed automatically, and it allows the teacher to mark attendance through the finger print sensor. We proposed a simple smart automation system which ranges from controlling of electrical devices in the room to the attendance marking through finger print recognition. Hence, it is proposed to develop an IOT based smart classroom system to perform many tasks such as taking attendance, detecting the faces using Cam detection and using Interactive whiteboard system with BOT. The system includes Interactive whiteboard (IWB) is a large interactive display board in the form of a white board. It improves the learning experience while making live classroom better. IWB permits teachers and students to be taught mutually, distribute files, use online resources and access educational softwares. Data analysis module is used to improve academic performance, academic records, attendance logs, disciplinary records and survey responses. Fig. 2 gives the details of the proposed work. The function of each module is explained in this section.

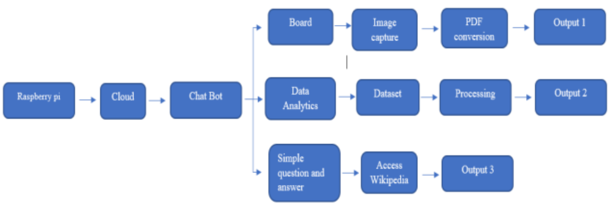


Fig. 2: Methodology in Proposed Work

Raspberry pi :

The Raspberry Pi 4 Model B is a versatile and powerful single-board computer. With its quad-core ARM Cortex-A72 processor and options for 2GB, 4GB, or 8GB of RAM, it offers significant performance improvements over its predecessors. Its multiple USB ports, including USB 3.0, expand connectivity options, while dual micro HDMI ports support dual 4K displays. Its GPIO pins enable interfacing with a wide range of devices, making it ideal for hobbyists, educators, and professionals alike. Raspberry Pi 4 Model B offers a compact and reasonable solution for various computing needs.

Cloud:

The cloud refers to a network of remote servers hosted on the internet, allowing users to store, manage, and process data without the need for physical hardware or infrastructure. It provides on-demand access to a variety of computing resources, such as storage, processing power, and applications, scalable to meet fluctuating demands. Cloud computing offers flexibility, cost effectiveness and accessibility, enabling individuals and organizations to innovate, collaborate, and scale their operations with ease. From simple file storage to complex data analytics and machine learning, the cloud empowers users to harness the power of computing without the constraints of traditional IT setups.

Chatbot:

A chatbot is a computer program designed to simulate conversation with human users, typically through text or voice interactions. Using natural language processing (NLP) and machine learning algorithms, chatbots can understand and respond to user queries in a conversational manner. They are deployed across various platforms such as websites, messaging apps, and voice assistants, offering assistance, answering questions, and performing tasks autonomously. Chatbots range from simple rule based systems to sophisticated AI powered models capable of understanding context and learning from interactions over time. They serve diverse purposes, including customer support, information retrieval, entertainment, and automation of routine tasks, enhancing user experience and efficiency in various domains. The chatbot section of the code comprises a graphical user interface (GUI) implemented using the Tkinter library in Python. It facilitates interactive communication between the user and the bot. The GUI features a chat history window where messages exchanged between the user and the bot are displayed. Users can input messages via a text entry field and send them to the bot. Upon receiving a message, the bot processes it, performing tasks such as querying wikipedia for information based on the user's input. The bot's responses are then displayed in the chat history window, creating a conversational interface for users to interact with the bot. Additionally; the GUI includes functionality for capturing and converting images drawn on a canvas to PDF format, demonstrating a diverse range of features beyond text-based conversation.

Board:

A smart board, also known as an interactive whiteboard, is a technology enabled display typically used in educational and corporate settings. It combines the features of a traditional whiteboard with interactive capabilities, allowing users to manipulate digital content using touch gestures or a stylus. Smart boards can display multimedia content, such as text, images, videos, and interactive applications, enhancing engagement and collaboration in classrooms and meeting rooms. They often integrate with computers and other devices, enabling real time annotation, sharing, and remote collaboration. Smart boards facilitate dynamic teaching, learning, and presentations, fostering interactivity, creativity, and productivity in modern learning and working environments.

Image capture:

Image capture on a smart board is a valuable feature that empowers users to capture snapshots of the display effortlessly. With just a click, teachers can immortalize moments of brainstorming, student presentations or visual aids, enhancing the learning experience. These captured images serve as digital snapshots of knowledge, ready for review or sharing with absent students, thus promoting collaboration and engagement. Seamlessly integrated with digital platforms, this option bridges the gap between traditional teaching methods and innovative technology, allowing educators to create dynamic and immersive lessons that resonate in today's digital age.

Pdf conversion:

Converting captured images into PDF format on a smart board adds a layer of versatility to educational resources. With this functionality, educators can compile snapshots of lesson content, student work or brainstorming sessions into a cohesive document. This streamlined process facilitates easy sharing and distribution, whether it's for review purposes or as part of a digital portfolio. By seamlessly integrating image to PDF conversion, smart boards empower teachers to create comprehensive learning materials that enhance collaboration, foster engagement, and adapt to the evolving needs of modern education.

Output 1:

Incorporating the capability to send converted PDFs directly to group emails on a smart board streamlines the dissemination of educational materials. This feature allows educators to effortlessly share important lesson content, student work, or collaborative projects with multiple recipients simultaneously. By eliminating the need for manual distribution, it enhances efficiency and ensures that all relevant parties receive the information promptly. Whether it's facilitating remote learning, coordinating group assignments, or fostering collaboration among colleagues, this functionality enhances the effectiveness of smart board technology in educational settings, promoting seamless communication and engagement across the board.

Data analytics:

Data analytics is the art of extracting meaningful insights from raw data. It involves collecting, processing, and analyzing vast amounts of information to uncover patterns, trends, and correlations. Through advanced techniques and algorithms, data analytics empowers organizations to make informed decisions, optimize processes and gain competitive advantages in various industries. From predicting consumer behaviour to optimizing supply chains, its applications are vast and transformative, shaping the way businesses operate in the digital age.

Dataset:

Datasets are the fuel that powers data analytics, serving as the foundation for analysis and insight generation. A dataset is essentially a collection of structured or unstructured data points that are organized for a specific purpose, such as research, analysis, or machine learning. These datasets can range from simple spreadsheets to complex databases containing millions of records. They come in various formats, including tabular data, text, images, and more, and can be sourced from diverse channels such as surveys, sensors, social media, and transaction logs. The quality, size, and relevance of the dataset greatly influence the accuracy and effectiveness of data analytics projects, making proper dataset selection and preparation crucial for successful outcomes. In the realm of education, an Excel sheet containing student data or performance metrics is a prime example of such a dataset. Here, each row represents an individual student, while columns delineate attributes like student ID, name, age, gender, grade level, attendance, test scores, and academic performance indicators. This dataset encompasses a wealth of information, including demographic characteristics, academic achievements, disciplinary records, extracurricular activities, and more.

Processing:

It initiates with the user selecting the target Excel file, from which data is to be extracted. Following this, the code loads the data, requesting the user to specify the sheet within the Excel file containing the pertinent information. Once the sheet is identified, the user is prompted to input a student ID, triggering the filtration of data to include only entries corresponding to the provided ID. Subsequently, the code extracts scores for each subject from the filtered dataset, assuming predefined column names for subjects (‘Subject1’, ‘Subject2’, etc.)

Output 2:

With the data extracted, the code proceeds to generate visualizations, comprising a pie chart illustrating the distribution of scores across subjects for the specified student. Furthermore, it crafts a timetable reflecting the student’s class schedule, influenced by the highest and lowest scoring subjects. Lastly, the visualizations are presented to the user, facilitating insights into the student’s academic performance and class schedule gleaned from the Excel data.

Simple question and answer:

Users can input queries which the bot processes and responds to it accordingly. This feature typically involves straightforward pattern matching or predefined responses based on keywords or phrases detected in the user input. The bot employs conditional logic to recognize specific questions or keywords and generates appropriate responses from a predefined set of answers or a knowledge base. This allows users to receive immediate answers to common queries or prompts, enhancing the bot’s usability and utility for providing quick information or assistance on commonly asked topics.

Access Wikipedia:

The chatbot leverages the Wikipedia API to access a vast repository of knowledge for answering user queries. When users input a question or topic, the bot utilizes the Wikipedia API to fetch relevant information from Wikipedia articles. It then processes this information, typically retrieving a summary or snippet related to the user’s query. By tapping into Wikipedia’s extensive database, the bot can provide users with accurate and detailed information on a wide range of topics, enriching their interaction experience with valuable insights sourced directly from a reputable online encyclopaedia.

Output 3:

After processing the user input or retrieving information from external sources like Wikipedia, the chatbot displays its response in the chat history window. This display response phase involves formatting the bot’s reply appropriately and presenting it within the user interface. The response typically appears as a new message in the chat history, attributed to the bot, and may include text, links, or other multimedia content depending on the nature of the response. This interaction loop fosters seamless communication between the user and the bot, enabling a fluid exchange of information and facilitating effective engagement with the chatbot’s functionalities.

3. Smart Monitoring System

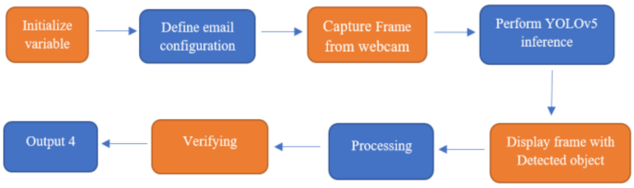


Fig. 3: Smart monitoring system

Initialize variable

In the code, the initialization of variables sets the groundwork for the subsequent operations in the smart classroom monitoring system as given in Fig. 3. These variables play critical roles in managing data, configuring email notifications, and facilitating the smooth execution of the program. Firstly, prev_person_count serves as a reference point to track changes in the number of people detected in each frame, ensuring accurate monitoring of classroom activity. The variable save_dir establishes the directory path where captured frames will be stored, enabling easy access to recorded footage for analysis or review. Meanwhile, frame_counter acts as a numeric identifier, ensuring that each captured frame is uniquely named and stored without overwriting existing files. phone_class_index, on the other hand, holds the index of the phone, class within the YOLOv5 model's output, enabling the program to identify instances of phone usage within the classroom. Additionally, the variables smtp_server, smtp_port, sender_email, sender_password, and receiver_email are pivotal for configuring the email notification system. These parameters are essential for establishing connections with the SMTP server and specifying sender and recipient email addresses, enabling the program to alert designated personnel in real time when phone usage is detected.

Define email configuration:

Defining email configuration parameters in the provided code is crucial for setting up the email notification system, which alerts relevant parties when phone usage is detected in the classroom. This configuration involves specifying key details such as the SMTP server address, port, sender's email address, sender's password, and recipient's email address. The smtp_server variable holds the address of the SMTP (Simple Mail Transfer Protocol) server responsible for sending the email notifications. This server acts as the intermediary for transferring emails between the sender's and recipient's email systems. Meanwhile, smtp_port specifies the port number used by the SMTP server for communication. By default, the common port for SMTP over TLS (Transport Layer Security) is 587, ensuring secure transmission of email data. The sender_email variable stores the email address of the sender, which is used to authenticate and authorize the sending of email notifications. Additionally, sender_password holds the password associated with the sender's email account, providing the necessary credentials for accessing the email server and sending messages. Lastly, receiver_email represents the email address of the recipient or recipients who will receive the email notifications when phone usage is detected. This variable ensures that relevant parties, such as educators or administrators, are promptly informed of any classroom incidents.

Perform YOLOv5 inference:

Performing YOLOv5 inference in the provided code is a crucial step where the pre-trained YOLOv5 model is utilized to detect objects, including phones, in the captured frames. This process involves feeding the RGB frames into the YOLOv5 model, which then analyzes the frames and identifies objects along with their respective confidence scores. The model variable, loaded using torch.hub.load(), represents the pre-trained YOLOv5 model. The captured frame, converted from BGR to RGB format, is passed through this model using the model() function, which returns the detection results. The results object contains information about the detected objects, including their bounding box coordinates, confidence scores and class labels. These results are then utilized to draw rectangles around the detected objects on the frame and label them accordingly using OpenCV's drawing functions. Additionally, within the loop iterating over the detection results, the program checks if any detected object corresponds to a phone based on the specified phone_class_index. If a phone is detected, the frame is saved, and an email notification is triggered to alert designated personnel about the detected phone usage in the classroom.

Display frame with detection object:

Displaying the frame with detected objects is a crucial aspect of the smart classroom monitoring system, as it provides real time visual feedback on the objects identified by the YOLOv5 model. In this process, the captured frame is augmented with bounding boxes and labels representing the detected objects before being displayed on the screen. Using OpenCV's drawing functions, such as cv2.rectangle() and cv2.putText(), bounding boxes are drawn around the detected objects, with labels indicating the object class and confidence score. This augmented frame provides a clear visualization of the objects detected within the classroom environment. The augmented frame is then displayed on the screen using the cv2.imshow() function, which opens a window titled, Smart classroom monitoring showcases the live feed from the webcam with overlaid bounding boxes and labels. This allows users to visually monitor the classroom activities and observe any detected objects in real time. By displaying the frame with detection objects, the system facilitates immediate visual assessment of the classroom environment, enabling prompt responses to detect events such as phone usage. This real time feedback enhances the system's effectiveness in monitoring classroom activities and maintaining a conducive learning environment.

Processing:

In processing, the dataset it drawing rectangles around detected objects plays a vital role in visually highlighting the objects identified by the YOLOv5 model. This process involves utilizing OpenCV's drawing functions to overlay bounding boxes onto the captured frame, visually indicating the location and size of the detected objects. By using the cv2.rectangle() function, rectangles are drawn around the detected objects based on their bounding box coordinates. These rectangles provide a clear visual representation of the objects within the frame, enhancing the system's ability to identify and monitor classroom activities in real time. Drawing rectangles around detected objects allows for quick and efficient visual assessment of the classroom environment, enabling staff members to promptly identify and respond to any detected events, such as phone usage. This visual feedback enhances the system's effectiveness in monitoring classroom activities and maintaining a conducive learning environment.

Verifying:

In checking if a detected object is a phone, is a critical step in identifying specific objects of interest within the captured frames. This process involves examining the class label assigned to each detected object by the YOLOv5 model and comparing it to the predefined class index corresponding to a phone. By comparing the class label's index to the predefined index for phones, the system determines whether the detected object is indeed a phone. Checking if an object is a phone enables the system to focus on relevant objects of interest within the classroom environment, facilitating targeted monitoring and intervention strategies. This targeted approach enhances the system's efficiency in detecting and addressing specific classroom behaviors, such as unauthorized phone usage, while minimizing false alarms and irrelevant notifications.

Output 4:

Upon detecting a phone within the captured frame, the program executes specific actions to address the identified event. Firstly, it saves the frame containing the detected phone to provide visual evidence of the incident. This action ensures that staff members can review the captured image to verify the phone usage incident and take appropriate measures. Additionally, the system sends an email notification to designated staff members to alert them of the detected phone usage in the classroom. The email includes relevant details, such as the time of detection and an attached image showing the frame with the detected phone. This immediate notification enables staff members to promptly intervene and address the situation, maintaining a conducive learning environment and upholding classroom rules and policies.

4. Results and Discussion

This work is used to develop a light automation system that monitor and control over all remotely controllable devices using IOT. As a result, before entering into the classroom first the student registers his/her finger in the finger print module. At that time by using that finger print the attendance of the student is marked in the database and at cayenne website/application as a excel sheet format. With the help of that fingerprint the door of the classroom is opened. When the student enters into the classroom, the two ultrasonic sensor senses and sends the signal to LDR humidity sensor. These sensors are then used to switch the lights and fans to ON/OFF in the classroom. The humidity sensor controls the fans speed based on the humidity level of the classroom. The LDR sensor controls the lights on/off. At the dark mode the lights are ON and for remaining time the lights are OFF. After the classes end when the student gets off from the classroom, the two ultrasonic sensors again senses and sends the signal to classroom door to open/close. That ultrasonic sensors also count the whole strength of the classroom i.e. the total students present in that classroom. By using the cayenne application/website, teachers can check the daily attendance of the student from the database and can able to download the details. Teachers can also able to check the humidity and light level of the classroom in a graph format via cayenne website/application with the help of IOT module.

5. Conclusion

In this work, the smart classroom concept is described from a completely new perspective i.e. real time feedback on lecture quality with IoT. Our work mainly focuses on use of the monitoring and sensing technology to explore the listener's behavior in an intelligent environment. The information collected presents insight into classroom tasks by correlating the sound and the movement existence and severity. The results showed that the IoT technology can be used to bring improvements to a household appliance also classroom with minimal amount of hardware. In further tests the accuracy of the results should be improved by running all phases simultaneously. It has been experimentally proven that classroom automation using IoT is working satisfactorily by linking the devices being effectively controlled. The planned system not only controls the light, the fans and the projector, but also takes the participation. This will help the teacher and students save time and focus on studying. The goal of the Smart Classroom is to make the use of the computer in the classroom simple, friendly and not intimidating as possible. In recent years, the utilization of distance education systems in all types has been mounting. One of the tools for the distance education system is perhaps intelligent classrooms, concurrent classroom environments. It is for that reason significant to increase the efficiency of the smart classroom to improve the remote learning environment education. The concept of Bring Your Own Device (BYOD) is being piloted so that it can be used extensively.

References

[1]Sajid, M., Hussain, R., & Usman, M. (2014, September). A conceptual model for automated attendance marking system using facial recognition. In *Ninth international conference on digital information management (ICDIM 2014)* (pp. 7-10). IEEE.

[2].Erdogmus, H. (2009). Cloud computing: Does nirvana hide behind the nebula?. *IEEE software*, *26*(2), 4-6.

[3].Reddy, C. S. S., Zaheer, A., & Saket, K. V. VP (2018) Smart classroom using Raspberry PI. *Int J Pure Appl Math*, *120*, 1871-1884.

[4].Zhong, X. L., Li, H. X., Xu, J. H., & Song, S. Q. (2017, August). Interactive teaching support systems in smart classrooms: research and practice. In *2017 12th International Conference on Computer Science and Education (ICCSE)* (pp. 9-11). IEEE.

[5].Kim, Y., Soyata, T., & Behnagh, R. F. (2018). Towards emotionally aware AI smart classroom: Current issues and directions for engineering and education. *IEEE Access*, *6*, 5308-5331.

[6].Scott, K., & Benlamri, R. (2010). Context-aware services for smart learning spaces. *IEEE Transactions on Learning Technologies*, *3*(3), 214-227.

[7].Yang, J., Pan, H., Zhou, W., & Huang, R. (2018). Evaluation of smart classroom from the

perspective of infusing technology into pedagogy. *Smart Learning Environments*, *5*, 1-11.
[8].Yuliantoputri, A. R., Muhamad, W., & Suhardi, S. (2019, November). Smart classroom services system design based on services computing system. In *2019 International Conference on ICT for Smart Society (ICISS)* (Vol. 7, pp. 1-6). IEEE.
[9].Mason, G. S., Shuman, T. R., & Cook, K. E. (2013). Comparing the effectiveness of an inverted classroom to a traditional classroom in an upper-division engineering course. *IEEE transactions on education*, *56*(4), 430-435.
[10].Bargaoui, H., & Bdiwi, R. (2014, November). Smart classroom: Design of a gateway for ubiquitous classroom. In *2014 International Conference on Web and Open Access to Learning (ICWOAL)* (pp. 1-4). IEEE.
[11].Srivastava, D. K., & Mathur, R. (2013, December). Innovation and technology in engineering education system based on Android. In *2013 IEEE International Conference in MOOC, Innovation and Technology in Education (MITE)* (pp. 285-288). IEEE.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.