Date of publication DEC-31, 2025, date of current version MAY-21, 2025.
www.computingonline.net / computing@computingonline.net

Print ISSN 1727-6209
Online ISSN 2312-5381
DOI 10.47839/ijc.24.4.4334

An Educational Laboratory Elevator with IoT/Cloud Utilizing

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ABSTRACT Nowadays, elevators are an essential part of everyday life, helping people move easily between floors in homes, offices, shopping malls, and more. Over the years, elevator technology has advanced to meet growing demands and keep pace with modern innovations. Today, smart elevators equipped with Internet of Things (IoT) technologies can gather data, monitor traffic, and enhance safety. This project idea grew out of our experience in the embedded systems lab, where we noticed that students often struggle to grasp how modern technologies especially IoT and cloud computing are applied in real-world systems. To bridge this gap, our research aimed to develop a working prototype of a smart elevator for educational use, capable of serving three floors and managed by an IoT-based control system. The prototype integrates various sensors to track elevator conditions such as floor position, cabin environment, door status, and live video via a surveillance camera. Data collected by the sensors is sent to the ThingSpeak cloud platform, which can respond appropriately to emergencies or misuse. Testing the system in the lab showed encouraging results, demonstrating its potential to help students better understand how to design and implement reliable embedded systems enhanced with IoT and cloud technologies.

KEYWORDS Elevator; Embedded systems lab; Internet of Things (IoT); ThingSpeak; Arduino platform

I. INTRODUCTION

Modern elevator history dates back to the 1800s as per [1]. Nowadays, intelligence plays a significant role in elevator systems. The internet is another element that has significantly changed our lives. In actuality, the internet is available in every circumstance, from straightforward communication needs to intricate ones. The Internet of Things (IoT), which aims to link every device to the network so that it can be used, prepared remotely, and watched over has gained a lot of attention recently. By employing these methods, we can consider utilizing the IoT to link the elevator to the network in order to track its condition and avert malfunctions as mentioned in [2].

An elevator is a critical and frequently used machine designed to transport people or goods vertically in high-rise buildings such as hotels, shopping centers, residential complexes, and office towers. To prevent elevator safety incidents, [3] emphasized the importance of developing an IoT-based elevator failure monitoring system. The paper introduced IoT technologies, processed relevant data, and continuously extracted elevator operation metrics using embedded sensors. The Relief-F algorithm was used to evaluate the key influencing factors. The authors suggested that their proposed system helps address the current lack of effective monitoring in the elevator industry.

According to [4], the IoT architecture is typically divided into three main layers: data transmission, data processing, and data services. The data collection layer focuses on capturing a variety of real-world data using different types of sensors. The transmission layer is responsible for receiving the collected data and forwarding it through the internet. The processing and service layer analyzes the data and enables monitoring personnel to respond appropriately based on the insights gathered.

Based on the concepts from [5–7], the Internet of Things (IoT) is a network of physical objects embedded with sensors, software, and connectivity features that allow them to collect and share data online. One of the key elements of IoT is the use of cloud computing services to store and process the data generated by these devices. ThingSpeak is a cloud platform designed specifically for IoT analytics and supports real-time data visualization. It is tightly integrated with MATLAB, which enhances its capabilities and makes it highly recommended for IoT systems. ThingSpeak offers ease of use compared to other open-source servers, providing simple configuration and built-in channel analytics. It collects sensed data from IoT systems, analyzes and visualizes the data, and can trigger predefined actions based on the analysis results.

Arduino is one of the most popular devices used with ThingSpeak. To use ThingSpeak with Arduino, the next steps are typically followed.

1) Create a ThingSpeak account and obtain the API keys.
2) Set up the Arduino device with the Ethernet or Wi-Fi shield.
3) Write the Arduino code to read data from sensors or other devices and send it to the ThingSpeak platform using the API.
4) Upload the code to the Arduino controller.
5) Monitor the data on the ThingSpeak platform and perform data analysis and visualization.

Data in ThingSpeak is organized into channels, which act as dedicated containers for specific sets of data. Multiple fields can be included within a single channel to represent various types of data collected from sensors or other devices. For instance, in a home monitoring system, a channel might have fields for gas, humidity, and temperature. With ThingSpeak, users can set up alerts and notifications to be triggered based on predefined thresholds or specific conditions. For example, if a gas sensor detects a leak at home, the system can automatically send a notification via email, SMS, or other platforms to alert users of the issue.

Integrating IoT with ThingSpeak capabilities in elevator control systems can bring significant improvements and innovative features. As discussed in [8], using IoT along with advanced sensors can enhance elevator monitoring by collecting data on variables such as noise, vibration, speed, and weight. These sensors continuously gather operational data, offering insights into the elevator's real-time performance. The design of the IoT-elevator system includes a wide-area network, enabling communication between on-site monitoring stations and a centralized remote-control center. This architecture supports centralized monitoring and allows for automated alerts in case of system faults.

In conclusion, the author emphasized that remote-control technologies significantly enhance safety and ensure a faster response during emergency situations involving elevator use. An example model of an IoT-enabled smart elevator is shown in Figure 1.

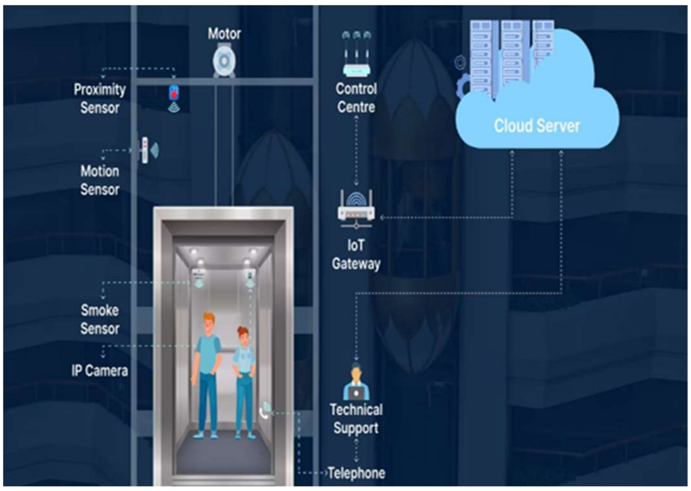


Figure 1. Typical diagram for elevator with IoT facilities

Our project was inspired by the difficulties we encountered while teaching embedded systems concepts in the laboratory environment. To overcome these challenges, we searched for an open-source solution that could effectively support hands-on learning. We chose the elevator system due to its clear operational structure and its value as a practical, real-world application. This setup enables students to develop a solid understanding of embedded systems, including both control mechanisms and remote monitoring capabilities.

This paper presents the design and building of a three-floor educational elevator system that integrates IoT and ThingSpeak cloud technologies within an embedded systems lab setting.

The remainder of the paper is organized as follows. Section 2 presents the literature review. Section 3 explains the research method. Section 4 reports the results and discussion. Section 5 provides the conclusion and summary of the paper.

II. LITERATURE REVIEW

To ensure the scientific foundation and relevance of our research, we review the literature from two perspectives:

1) Studies focus on developing educational elevator systems for lab implementation.
2) Studies focus on elevator systems incorporating IoT and cloud technologies.

A. STUDIES ON ELEVATORS FOR EDUCATIONAL PURPOSES

Work [9] developed an elevator simulation as one of the experimental setups. This setup allowed students to program and control a model elevator system using Programmable Logic Controller (PLC), simulating real-world elevator operations. The designed educational lab set enabled the students to understand applying PLC programming concepts to manage elevator functions like floor selection, door control, and safety mechanisms. The paper showed a well-designed method to enhance students' understanding of automated systems. [10] developed a prototype elevator that monitored and controlled in real time using PLC. The system has been implemented on a lab-sized elevator prototype. A new method for traction-based elevator system was introduced which didn't need a counterweight. Servo motor (Mitsubishi's HJ-KS43J) was used as the prime mover for its accurate positioning capability. SIEMENS S7 200 SMART PLC was used for controlling the entire system. PLC is interfaced with hooters, floor switches, indicators, and sensors for effective functioning of the elevator system. This prototype serves as an appropriate model demonstration in a lab.

Work [11] provided an overview of the planning, execution, and management of a lab model of Elevator. The authors concentrated on the PLC equipment's hardware and software components. The model is placed in the lab on Department of Cybernetics and Artificial Intelligence at the Technical University in Kosice. The elevator was a teaching tool used to apply different algorithms and programs in ladder diagrams. The suggested control's functionality validates the experimental model, and the outcomes were compared in various scenarios. The present model can be configured differently and used in teaching courses such as distributed control systems. Work [12] concentrated on describing a lab elevator model for education purpose. The paper presented algorithms for regulating the elevator's cabin speed and position for purposes of traffic control. The elevator contained four floors. On every floor there were two position sensors and cabin call button. Cabin speed regulation is realized by programming code using Arduino platform, incremental encoder and chopper to control a DC motor speed. The elevator model was useful for lab exercises because the controlling parameters were easy to be changed and followed.

In [13] the researchers focused on lab experiments to improve elevator system performance. The researchers tested various control algorithms and configurations in a controlled environment to reduce wait times and enhance energy efficiency. This hands-on approach provided valuable insights and practical experience, reinforcing theoretical concepts to help students understand elevator system optimization through real-world application and experimentation. Work [14] designed a three-story, multifunctional training elevator. This elevator was a form of educational tool intended for use in the mechatronics, electric, and electronics department of vocational-technical education institutions. The quality, durability, and efficacy of the lessons students learned increased with the use of this elevator training set. Through the utilization of the elevator training set, the students acquired the ability to operate the elevator via PLC, SCADA, or microcontroller. As a result, they developed their software skills and self-confidence via the realistic application.

Work [15] explored the creation and effectiveness of a virtual-reality system designed to train elevator maintenance personnel. The system simulated real-life scenarios, providing a hands-on learning experience without the risks associated with actual maintenance tasks. The authors detailed the design process, implementation steps, and evaluation methods used to assess the system's educational impact. Overall, the paper highlighted the potential of virtual-reality technology in education and training. Work [16] suggested and created an elevator control system prototype. In the lab, this prototype served as an experimental model. The bottom floor, first floor, and second floor make up its three levels. The 4x4 Matrix Membrane Keypad served as the human interface component in the control circuit architecture of the built elevator, which used the Arduino Uno as its primary controller. The mechanical design including the dimensions, sizes, weights, calculations, and analysis of the elevator's prototype, was presented and evaluated.

Work [17] focused on developing a computer model to simulate the behaviour of a two-speed elevator system. The model incorporated both mechanical and electrical components to accurately represent the system's dynamics. By using this simulation, the study aimed to analyze and optimize the elevator's performance, addressing issues such as energy efficiency and ride comfort. The model helped the trainees in the lab to predict system behaviour and design better elevator control strategies.

B.. STUDIES ON ELEVATORS WITH IoT INTEGRATION

Work [18] talked about a particular type of internet of things-based elevator monitoring system. The end user computer, maintenance party, remote monitoring computer, and numerous sets of elevator monitoring terminals made up the system structure. Every monitor terminal has an elevator connected to it so that data processing and analysis can be done in addition to learning about the elevator's current operating status. Each monitoring terminal was primarily made up of an Ethernet module, touch screen, USB module, signal acquisition module, data storage module, and Samsung embedded processor S3C2410, which is based on the ARM processor architecture. Many pieces of information can be retrieved using multi-sensor information acquisition, including the elevator's direction, speed, floor, door switch, or if anyone was in the elevator, etc. The Ethernet then formed a multi-elevator remote monitoring and automatic alarm network by connecting the monitoring terminals to the maintenance party, remote monitoring center, and end user. The study in [19] discussed the design and implementation of a smart elevator system using advanced technologies such as IoT and AI. The system aimed to optimize elevator operations by predicting maintenance needs, and enhancing user experience through real-time monitoring and data analysis. It integrated various sensors and machine learning algorithms to dynamically manage elevator traffic and reduce downtime.

Work [20] delved into the integration of IoT technology to revolutionize the maintenance of elevators. The authors proposed an IoT-based predictive maintenance system. The system was designed to monitor the health and performance of elevator components in real-time using an array of IoT sensors. These sensors were placed within the elevator system to capture vital data, such as motor temperature, vibration levels, and door operation metrics. The collected data was then transmitted to a central processing unit where advanced algorithms analyzed it to detect potential failures. The paper also discussed the integration of this IoT-based system with existing elevator infrastructure without significant modifications. The work in [21] introduced an IoT device for remote elevator control, which can transform a manually operated elevator into a remote-controlled system without requiring intrusive modifications. The non-contact add-on device was placed over the existing button panel and used servomotors to press the buttons. This design allowed for rapid deployment, improving accessibility through messages, a webpage, or a QR code. Experimental evaluation confirmed its effectiveness, making it suitable for pandemic conditions and use by autonomous robots.

Work [22] established an elevator monitoring and alarm system includes elevator, monitoring terminals, WiMAX base station, local server, central server, monitoring PC and hand-held intelligent terminals. The system integrated fault detection, trapped people communication and information management to notify maintenance staff. Multiple sensors were allocated in different parts of elevator. The design of the wireless monitoring that based on WiMAX technology showed the capability to fulfil the demands of the IoT. In [23], the researchers explored the application of IoT technology to implement condition-based maintenance (CBM) for elevators. Utilizing real-time monitoring and data analysis, the system anticipates potential failures, thereby enhancing reliability and safety. The authors argue that transitioning from traditional maintenance methods to a proactive, data-driven approach significantly reduces maintenance costs, minimizes downtime, and improves service quality.

Work [24] proposed an IoT-driven elevator system aimed at optimizing traffic management and boosting time efficiency. By leveraging real-time data from IoT sensors, the system anticipated and managed elevator demand, leading to reduce wait times and enhance performance. IoT integration enabled the system to adapt dynamically to user behaviour and building occupancy. The paper assessed the system's effectiveness through simulations and practical deployments, showing notable gains in both elevator efficiency and user satisfaction. To decrease elevator accidents, [25] focused on the creation of an IoT application that allowed the maintenance business and technician to monitor the elevator's status in real time and get information about emergencies or scheduled repairs. The elevator communication module, the IoT platform, and the front-end software application formed the system. The data taken from the elevator's vital systems and be sent to the IoT platform through the communication module, where it was stored, viewed, and analyzed. The data was then sent to the mobile application. Here, the maintenance firm would be notified of any emergency or planned maintenance period through the front-end mobile application. The research's goal was to make elevator ride safer for passengers by providing timely maintenance and prompt emergency response.

Work [26] built an intelligent monitoring system of elevator IoT based on multi-sensor information fusion, bus communication and probability and statistical analysis technology. Managers can access the control platform through smart terminals or web browsers to achieve data query, video monitoring, alarm management of the elevator system, health management and other functions. These facilities can help managers detect hidden dangers of elevator safety in time and ensure safe and efficient operation of elevator. Work [27] offered a real-time elevator monitoring system that used real-time operation data gathered from many sensors to quickly and correctly diagnose elevator faults and abnormal states. The web client on several platforms made it simple to obtain the real-time monitoring result over a local network. It may also be sent to a cloud platform to enable distant access.

Elevint is the name of the IoT cloud-based mobile defect detection application that [28] worked on developing. The system is a mobile application that linked elevator owners with technicians and maintenance businesses. It allowed users to schedule routine maintenance and see maintenance history in addition to sending and receiving messages. In this system, the status of the elevator is monitored in real-time i.e., the elevator's current floor, temperature, vibration among others. The data gathered from the sensors is sent to the Fire Base real-time cloud-hosted database using rules determined by experts, through which it gets sent to the mobile application. The mobile application was set up to show updated sensor data at 25-second intervals (changeable). For the hardware platform, the system used a computer with Windows operating system and used Arduino to create the circuit in which the sensors get connected. As for the software platform, the system uses Basic4Android and Visual Studio to create the application. A cloud-based web application was proposed by [29] for online tracking of the location and malfunction details of a three-story elevator. The fault identification was a two-stage process. Firstly, the rotary encoder provided the information about the motion of the elevator then the level sensor outputs indicate the floor number or the fault condition. An Arduino controller with ESP32 Wi-Fi module was used for sensing, processing the information then sending to ThingSpeak channel. The ThingSpeak was used to display graphs to monitor if an error occurred and in which floor.

A smart sensor node tailored for Internet-of-Elevators (IoE) systems was proposed by [30]. This sensor node is engineered to monitor elevator conditions and detect faults without invasive methods, gathering data on parameters like vibrations, speed, and door operations. The collected data is sent to a cloud-based platform for real-time analysis, facilitating predictive maintenance. The system is designed for easy deployment, improving elevator reliability by minimizing downtime and preventing unexpected failures through continuous internet-based monitoring. Work [31] presented an IoT-based device and method for monitoring elevator levelling failures, ensuring precise floor alignment. Elevator signals were obtained from the Controller Area Network (CAN) bus interface, transmitted to a remote monitoring platform, and stored in a private data center. The system used sensors to detect any misalignment in elevator levelling, triggering alerts to prevent accidents and ensure safety. This approach enhanced reliability by providing real-time monitoring and a quick response to potential levelling issues.

In [32], a remote-control elevator system was constructed. The design process started with a questionnaire with the help of experts to outline the issues. As a result, they suggested the components of an intelligent elevator system, together with the relevant sensors and devices and installation locations. Many remotely monitored tasks were included in the plan, such as turning off the main power supply, regulating the elevator's speed, turning on the main safety circuit, opening and shutting the doors, determining whether the elevator is overloading, and more. The authors anticipated that a design based on the study's findings will aid in development of a more intelligent elevator supported by a remote-control system.

III. RESEARCH METHOD

Designing an educational lab elevator with IoT/cloud (ThingSpeak) utilization involves integrating various technologies to create a smart, efficient, and educational environment. In this project, we have implemented a typical embedded system using an elevator prototype for training students in the lab, while ensuring safety, reliability, and compliance with educational standards.

This section will be divided into several stages. The first stage is the building of the elevator body. Then the hardware components used to control and monitor the elevator are described. Then the most important parts of the software are explained.

A. BUILDING THE ELEVATOR STRUCTURE

Building a model of a smart elevator is the aim of this project, which this paper based on. The model is used as a training set to teach the students the components of an embedded system that use the IoT for monitoring and control in the lab. While designing the elevator structure, a number of factors are taken into consideration. First and foremost, the materials must be lightweight and durable enough to endure students' continuous use in the lab. In addition, the model's proportions should be suitable for easy transportation when necessary. Lastly, consideration is given to the connections and functional components of the elevator, including the motor, sensors, etc. These components should be in visible places in order to facilitate their viewing and studying by the students. Figure 2 shows different views with dimensions for the structure that makes up the designed elevator model.

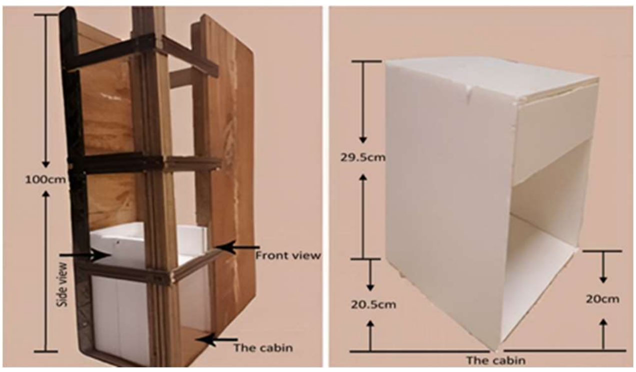


Figure 2. Structural view of the elevator during assembly

B. CONTROL AND MONITORING HARDWARE SYSTEM

A block diagram of the hardware system is shown in Figure 3, which includes the Arduino Mega controller and all input and output equipment. To deal with the system remotely, a software code is built to communicate between the Arduino platform and the ESP8266 board that provides IoT services. This IoT facility is used to transfer the sensors readings to the ThingSpeak cloud for monitoring and analyzing.

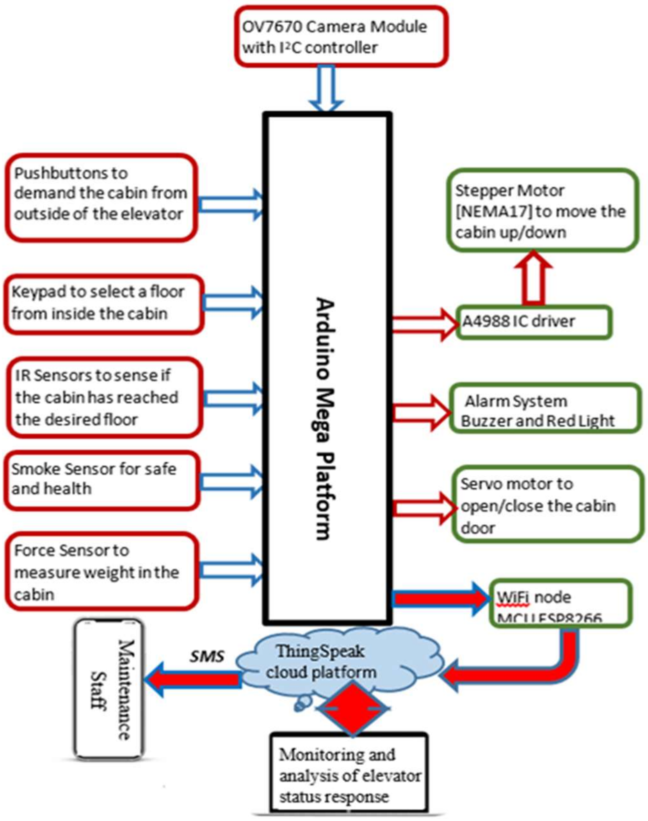
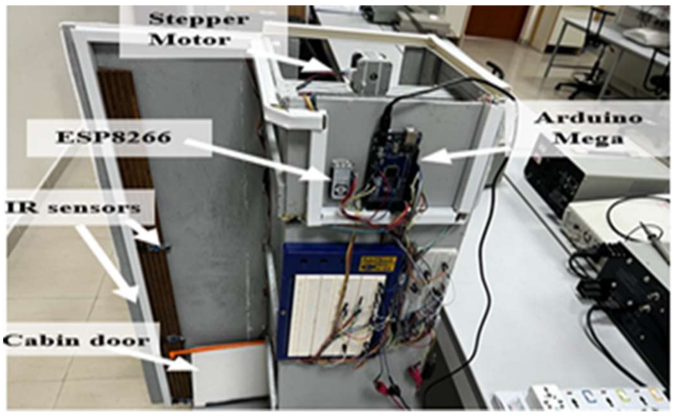
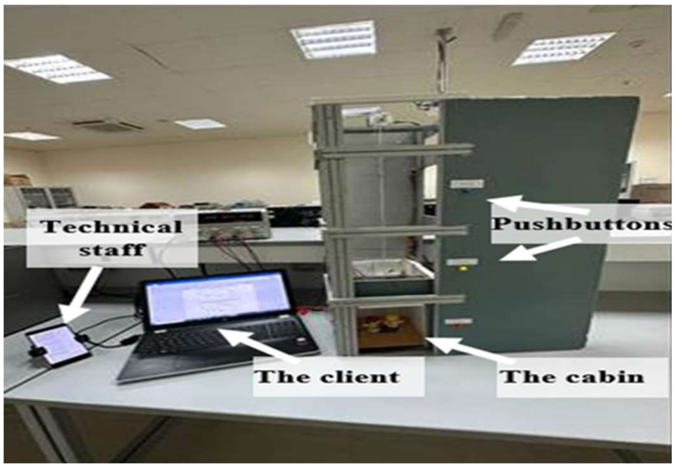


Figure 3. Block diagram of the system architecture

Figure 4(a), Figure 4(b), and Figure 4(c) show the exterior of the elevator, the interior of the cabin, and the various parts mounted on the elevator chassis, including Arduino Mega, the sensors, the stepper motor, and other parts. Also inside the cabin, the camera and other components such as the air quality sensor and the excess weight sensor are shown to provide safe condition for elevator passengers. To enable remote monitoring of the elevator, a client computer and the technical staff's mobile phone are used, as illustrated.



(a)



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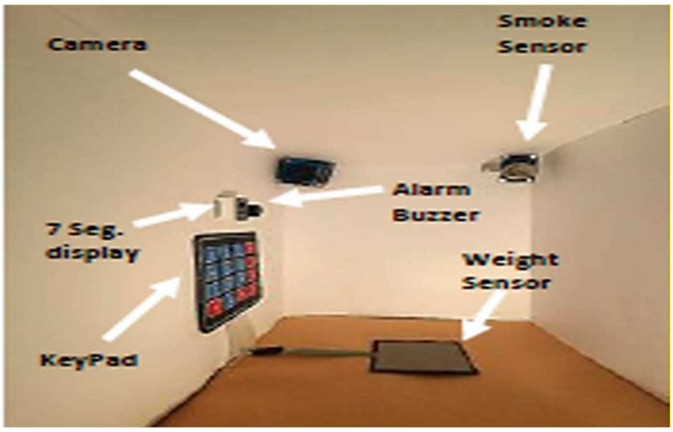


(c)

Figure 4. Elevator model after completion. (a) Side view, (b) Front view, and (c) The inside of the cabin

C. CAMERA USED IN THE ELEVATOR CABIN

Referring to [33], the OV7670 camera is an Arduino Mega-compatible VGA camera with a 640×480 resolution and 30 fps. Despite its low quality, it is sufficient for the lab's training elevator. It interfaces via I2C (pins 20, 21), with an 8-bit data output connected to Arduino pins. Handshaking signals (VSYNC, HREF, PCLK) use pins 3, 8, and 2 of Arduino Mega. The camera operates on Arduino's 3.3V. Figure 5 presents a sample shot captured by the cabin camera.

Figure 5. Video frame from inside the elevator cabin

D. ARDUINO MEGA HARDWARE COMMUNICATION WITH IoT

As described in references [34, 35], the ESP8266 module is the most commonly used Wi-Fi SoC (System on a Chip) for IoT applications. This is because it offers a set of essential core Wi-Fi features and functions. Consequently, the ESP8266 is often used as a gateway, enabling microcontrollers to exchange data and information over the internet via the UART serial port. The board, designed and developed by Shenzhen Doctors of Intelligence & Technology (SZDOIT), responds to AT commands, so the AT firmware must first be installed. Once installed, the module can connect to a network and access the internet. The ESP8266 and Arduino communicate serially. Therefore, pins 16 and 17 on the Arduino Mega board, which function as TX and RX, are utilized.

A detailed representation of the remote monitoring system is given in Figure 6. This module represents the communication between the Arduino and NodeMCU ESP8266 to send sensors data to the ThingSpeak. In this case, ThingSpeak visualizes the collected data, granting access to the data remotely, in addition to integrating MATLAB support in case of additional analysis. The data on the ThingSpeak gets stored in channels and each channel has unique read and write API keys. Although many factors influence the operation of an elevator, only three parameters were selected for this model, as it is intended for lab use. These parameters were chosen to simulate a typical embedded system in a standard elevator. The selected parameters, along with their safe operating ranges, are summarized below.

1) Air quality: For health concern, the air quality index (AQI) inside the cabin should be less than 100.
2) Floor level: The position of the floor should 1,2, or 3 since the elevator consists of three floors.
3) Elevator load: This parameter is to monitor the weight inside the cabin which should be less than 250 g. This weight is reasonable since the elevator capability is designed for educational purpose to train the students in the lab.

The emergency state is a critical safety feature in the elevator control system, represented by a binary flag: 0 for normal operation and 1 for emergency conditions. The system continuously monitors various sensor inputs, and if any predefined safety threshold is breached, the Emergency State is set to 1. Specifically, the elevator is equipped with the following safety-related sensors:

- The system checks if the total weight inside the cabin exceeds the maximum rated capacity the emergency state is triggered to prevent motor overload and mechanical failure.
- The system monitors for air quality. If smoke concentration exceeds a safety threshold, the system sets the emergency state and activates an alarm.
- The system ensures that the elevator cabin is properly aligned with a floor before opening the door. If the IR sensor fails to detect alignment with any floor while the door is open, or if there's a mismatch between expected and actual floor levels, the system flags a positioning error and sets the emergency state.
- The system monitors the door status sensor (limit switch) to checks whether the cabin door is fully closed during movement. If the door remains open or partially open when the elevator is in motion, the emergency state is activated to halt the elevator and prevent accidents.
- The system includes an emergency button located on the user control panel, this allows passengers to manually activate the Emergency State by pressing the button in case of panic, illness, or other urgent situations.

When any of these conditions are met, the system sets the emergency state to 1. This value is immediately sent via the IoT module (ESP8266) to the ThingSpeak cloud platform, enabling real-time logging, visualization, and remote alerting. Simultaneously, the system may halt the elevator, sound a buzzer, and/or notify support personnel for rapid intervention.

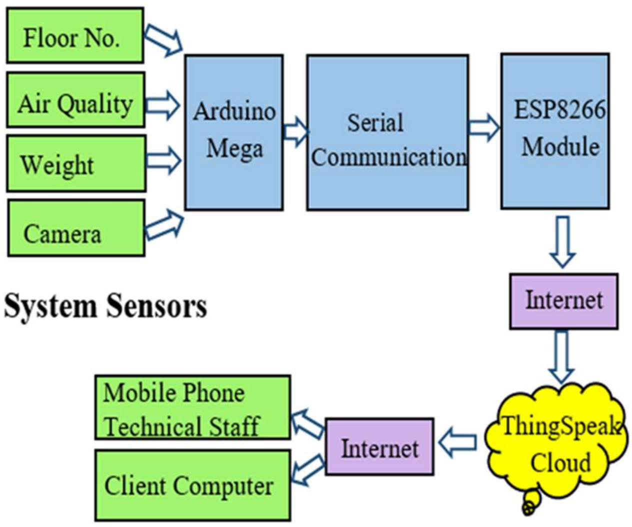


Figure 6. Integration of IoT capabilities with the system

E. SYSTEM SOFTWARE

The elevator control and monitoring program has been developed using the Arduino platform and C programming language. The program consists of two main parts. The first is referred to as the program for managing sensors, and the second is the program for remote monitoring. The sensors handling program is where the Arduino gathers data from sensors, like the air quality sensor in the cabin, the load sensor to warn about too much weight inside the cabin, the IR sensor to identify which floor the elevator is on, the camera for regular monitoring of passengers inside the elevator cabin, etc. These sensors continuously send data to the Arduino microcontroller, which processes the input in real time. This allows the system to make immediate decisions, such as stopping the elevator when the weight limit is exceeded or notifying about air quality issues. So, the Arduino can then control the elevator to fulfil requests to go up or down between the floors in a safe and reliable manner. The second part, which is the remote monitoring program, uses ThinkSpeak and IoT to analyse the sensors data received over the internet and perform any necessary response if needed. Remote access allows maintenance teams to monitor elevator performance and receive alerts without being physically present at the location. This proactive approach improves safety and reduces response time in case of anomalies. The actual components of the program are organized into modules, each tailored to a specific operational function of the elevator, as depicted in Figure 7.

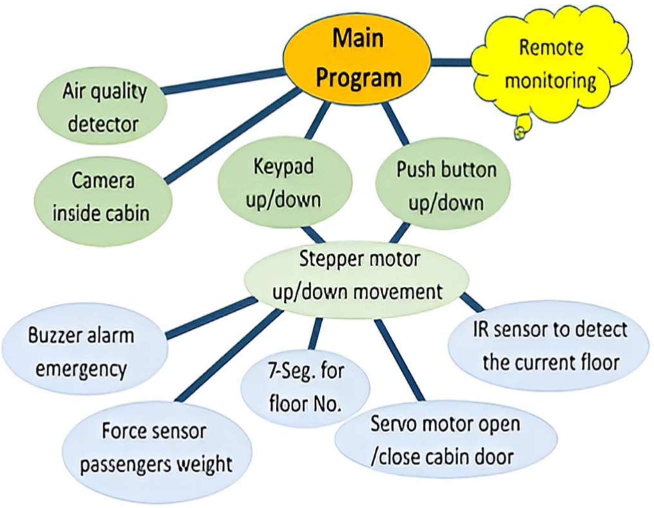


Figure 7. Main modules of the software system

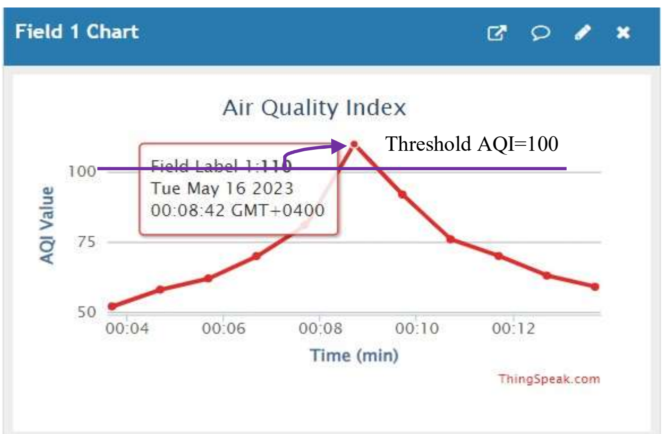
IV. RESULTS AND DISCUSSION

This project resulted in the design and building of an elevator training system. The goal is to use this system to assist the students to learn various parts of a typical embedded system and its functionality in a quick and efficient way. The results are presented and evaluated in the following subsections.

A. EXPERIMENTAL RESULTS

During lab time, the students conducted specific experiments on the elevator. In these trials, eleven distinct situations were applied to the sensors that correspond to various elevator measured parameters. ThinkSpeak remotely monitored and displayed the output of these parameters channels on the client computer's screen.

Figure 8(a), Figure 8(b), and Figure 8(c) show the visualization of data values obtained from the ThinkSpeak channels for AQI, floor number, and passenger's weight inside the cabin respectively. Two critical cases are shown in Figure 8(a) and Figure 8 (c). One is for the AQI which exceeded the pre-set safe limit 100, and the other is for overweight which exceeded the pre-set maximum weight 250 gm.



(a)

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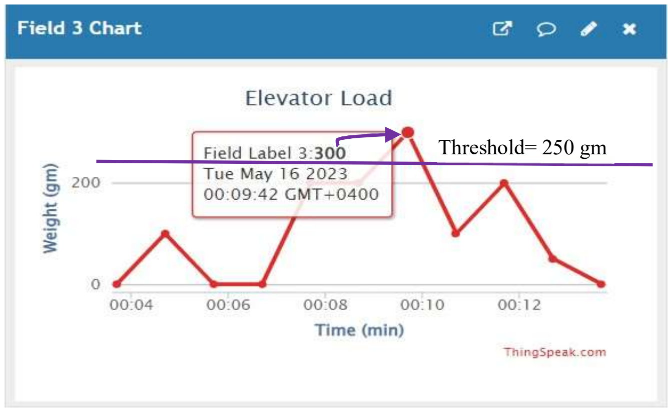

(c)

Figure 8. Data from ThingSpeak channels. (a) Air quality, (b) Floor No., and (c) Elevator load inside the cabin

Figure 9 shows a snapshot of the client screen displaying the real-time status of the elevator, including the current floor, air quality, cabin weight, and door status (open or closed). In this example, an overweight condition is shown, with the cabin weight reading 300 grams. Any critical condition like this is instantly sent via SMS to the technical staff's mobile phones to alert them and prompt a quick response.

Additional lab experiments were carried out to help students learn how to analyze sensor data received through ThingSpeak channels. The results were used to build a database that tracks the elevator's operation over time, such as the most frequently used floors, the number and types of emergency situations, and other key information.

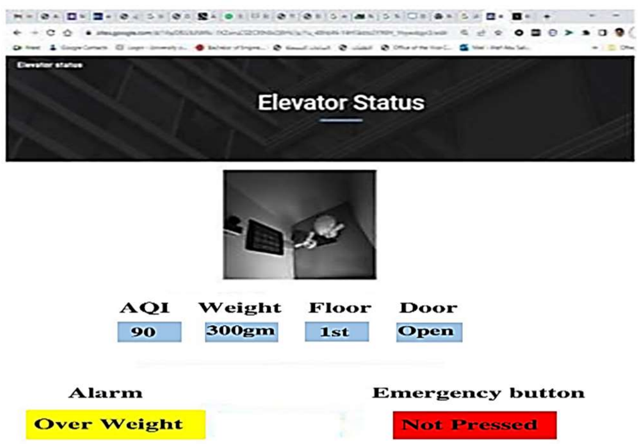

Figure 9. A screen shot from the client computer screen

B. STUDENTS' EVALUATION OF THE SYSTEM

This research aims to build a typical lab elevator model to enhance students' understanding of embedded system control and monitoring. Students tested and evaluated the prototype to support more reliable and efficient future improvements.

A questionnaire was given to 20 students in the embedded systems lab, covering topics such as system performance, utility, flexibility, clarity, and how closely the design resembles a real elevator. Table 1 outlines these categories, while Figure 10 displays student satisfaction levels for each category using distinct patterns. It is important to note that if a student expresses dissatisfaction with a specific evaluation category, that category is omitted from the column corresponding to that student.

Table 1. Topics of evaluation categories

Evaluation category	
1	Effective for learning in embedded systems lab
2	Flexibility of use in the lab
3	Quality of material used for the structure of the elevator
4	Clarity of hardware and wiring system on the model
5	Achieving all the characteristics of a real elevator

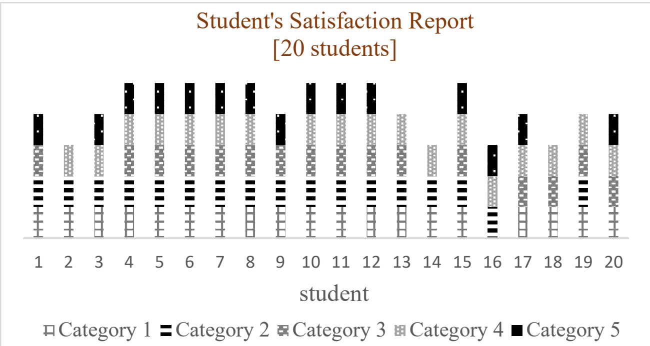

Figure 10. Students' satisfaction evaluation of the system

The findings of the surveying report is sumarized in Figure 11 as a percetage of satisfaction of all the students for each evaluation category. Overall, The students' answers indicate that they are content with the use of the designed prototype in the lab, where the ratings ranged from 75% to 95%.

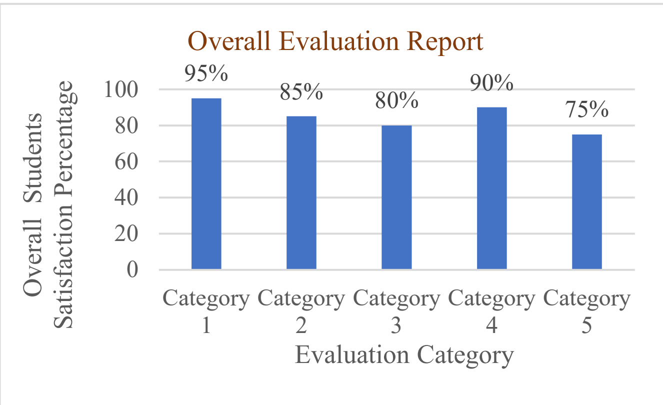

Figure 11. Overall percentage of students' satisfaction for each category in the system evaluation

However, the students also provided insightful remarks that need be incorporated into the model to enhance the design, as follows.

1) Malfunction detection and monitoring.
2) Speed control during upward and downward movement.
3) Passenger safety during cabin entry and exit.
4) Backup power supply.
5) Authorized access management.
6) Emergency lighting and ventilation.

These observations are important for grasping the characteristics of a real elevator system and will be carefully considered when upgrading the designed model in the future.

IV. CONCLUSION

Based on our teaching experience in the embedded systems lab, we noticed that many students struggled to fully understand and engage with hands-on experiments involving embedded systems. To help overcome this challenge, our lab team took the initiative to create a practical, relatable prototype that could make learning more accessible. We chose to build a model of an elevator system, as it is a familiar and intuitive example of how embedded systems function in everyday life. To enrich the learning experience, we also integrated IoT capabilities using the ThingSpeak cloud platform, enabling remote monitoring and control.

Once the prototype was completed, it was actively used in lab sessions at the University of Nizwa in Oman, within the Electrical and Computer Engineering Department. After a full semester of use, students showed noticeable improvements in both understanding and applying embedded system concepts.

To assess its effectiveness and identify areas for improvement, we gathered feedback through a questionnaire completed by 20 students who worked directly with the prototype. The responses were overwhelmingly positive, with satisfaction scores ranging between 75% and 95%, as illustrated in Figure 11.

Looking ahead, we plan to refine and enhance the elevator model by addressing the issues highlighted during the evaluation and incorporating students' feedback to make the next version even more effective as a teaching tool.

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