A Proposed System to Enhance Laboratory Safety and Efficiency Based On Esp32 Microcontroller

نظام مقترح لتعزيز سلامة وكفاءة المختبرات يعتمد على متحكم Esp32

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Abstract

The Internet of Things (IOTs) is a platform for automating user activities in society with the help of machines, it helps enable innovative services by connecting physical and virtual objects, intelligent interaction and communication between machines, Environmental monitoring in laboratories and manual operations are still present, Human supervision and processes are needed to perform tasks, With the advancement in technology and work procedures, smart laboratories have emerged to improve the workflow in laboratories and reduce the workload on employees inside the laboratory. Hence, a smart laboratory automation system was created, The system will monitor changes such as temperature, lighting, ventilation, and door and window opening and closing systems, Automation allows the user to control the laboratory remotely through his phone and also through the motion sensor and determine the actions that should occur based on time or other sensor readings such as light, temperature, humidity, or control of doors and windows in the automation network, which reduces human intervention and thus uses energy efficiently and saves time and effort. The proposed system works on the Esp32 microcontroller as the main controller, it connects all devices to the smartphone through Arduino IDE and MIT app Inventor via Wi-Fi.

Keywords: Esp32- MIT app inventor- Arduino IDE- Proteus IDE-Sensors -Smart Lab-Firebase.

1. Introduction

IOTS has revolutionized the way we interact with the world around us. With the increasing availability of IoTs devices and applications, there is a growing need to explore their potential to enhance security and efficiency in various fields including laboratory research, the integration of IoTs devices and applications can provide new insights into the performance of laboratory equipment and processes, enabling better monitoring and control to enhance security, reliability, and efficiency (Abderrahmane.T etal., 2024) Automation is the process of making a system intelligent so that it operates with little or no human intervention, It is essential in industrial processes such as controlling pressure, temperature and humidity (Owojori. A. et al., 2021) IOTS is an extension of the Internet to everyday objects, allowing them to be smart, that is, able to communicate and exchange data over the Internet, mostly using wireless communication technologies. Among these objects are automatic door operators, light bulbs, refrigerators, thermometers, and more (Ghoul. Y & Naifar.O 2024), The research on laboratory management in international universities is still ongoing, but due to the complexity, flow and ambiguity of the laboratory management process itself, the overall level and quality of management in many laboratories are not very high. Laboratory management can generally be divided into two categories: traditional manual management and information system management. In terms of traditional laboratory management, it still relies more on a dedicated administrator model. Starting from the general function of the laboratory, it is responsible for the systematic management of fixed or experimental assets such as experimental equipment, consumables and reagents, As well as registration and daily management of laboratory users. The traditional management method requires manual registration or registration by laboratory management personnel (Xiao.X 2024).

The laboratory provides an environment conducive to systematic inquiry and experimentation, enabling researchers to test hypotheses, validate theories, and make meaningful contributions to their respective fields as integral spaces within colleges and universities, laboratories play a pivotal role in the education and professional development of students (Odoh. F et al 2023).

The goal here is to build a smart laboratory that controls the laboratory environments by controlling temperature, lighting, door and window opening. The system will analyze and process the collected information and then produce the appropriate results. This will help in the automation and efficient energy consumption of the laboratory. The system will be able to adapt to the environment and act accordingly. This means that the devices will be used only when needed. Laboratory automation will help in efficient use of devices with minimal human assistance.

2. Related Works

The authentication protocol for IOTs devices is to protect the identity of the devices, the server can recognize authentic or registered IOTs devices and reject illegitimate, unregistered, or counterfeit devices (Shah. N etal.,2023),The system extends from home automation technology to college laboratories thus creating a smart laboratory that reduces the amount of energy consumed during the day thus the system helps the management in energy efficiency, lab automation also leads to better organization and reduces employee involvement in simple administrative tasks (Banagar. A& Khattar.R 2020) A security monitoring system based on IoTs technology enables the user to monitor and control the door remotely and receive an alert if movement is detected near the door The door allows access to trusted people to control the door Allows viewing the door entry log and user access log Get a notification that the door is still open after the specified time (Aldawira, C et al., 2019). Implementation of a smart laboratory created via IoTs and mobile communication technologies to supervise the general activities of the laboratory including energy consumption, application of devices and sensing environmental parameters thus providing a smart environment with balanced energy consumption and comfort where the system monitors the consumption pattern of devices and uploads it to its server and creates a control unit to remotely control the devices from anywhere thus reducing energy waste (Poongothai, M et al., 2018) ESP32 is a dual-core 32-bit microcontroller with inbuilt WIFI and Bluetooth modules (Jahnavi, T et al., 2022) the source code is stored in the on-chip memory provided in the ESP32, this block can be thought of as an interface between the programmer and the user. Therefore, it is considered the heart of the proposed system, ESP32 operating voltage range is 2.2 to 3.6V. Under normal operation, the ESP32 thing will work if the chip is at 3.3V ESP32 pin description (Pravalika. V & Prasad. C 2019), Temperature Sensor: The primary function of the DHT11 is to provide direct digital temperature values. The accuracy of the DHT11 is 20-90% relative humidity and 0-50°C temperature values in Celsius. The operating voltage is 3.3-5V (Tippannavar.S et al.,2022), The Firebase cloud server platform enables us to perform real-time data transmission and device communication. This platform includes a real-time database, analytics and performance monitoring, crash reporting capabilities, and networking, Since Firebase is powered by Google, it has the highest level of security as personal data will be protected (Mustofa. A et al., 2023), The Arduino IDE software application provides a platform for writing, compiling, and uploading code to Arduino supported boards The Arduino IDE provides an easy-to-use interface and includes (1) a code editor, (2) a library manager, (3) a board manager, (4) a serial monitor, and (5) Compilation and upload Tools the editor is used to write Arduino sketches or programs (Hercog. D etal., 2023), Proteus IDE is a systems simulation and virtual circuit simulation (VSM) application software, it also has a virtual studio, a free universal IDE for Proteus, in addition to its database component, more components can be designed as part of the library component if they are not part of the original software library (Amoran . A etal., 2021).

Many previous studies have focused on developing smart laboratory security systems by controlling the laboratory through IoTs and smartphone technologies, but they control it closely. However, in the current system, the laboratory's teaching environments are controlled remotely and anywhere, and events are recorded in real-time in a Firebase database.

The figure1 shows The IOTs architecture is divided into 4 different layers which are the sensing layer, the network layer, the data processing layer, and the application layer (Gupta. B & Quamara. M 2020).

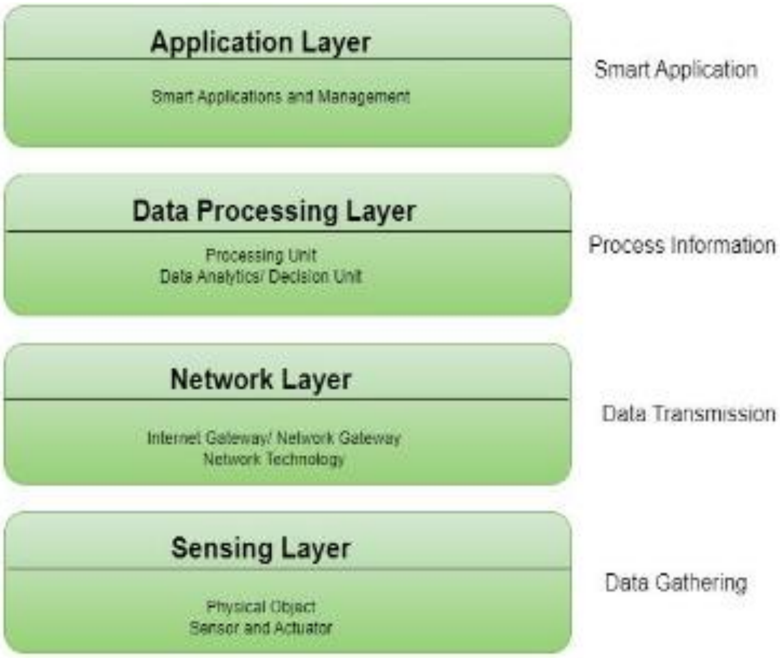

Fig1: IOTs architecture (Gupta. B & Quamara. M 2020).

3. METHOD

The system is implemented using an ESP32 microcontroller, the Arduino programming language, and the Android mobile app MIT App Inventor. Microcontroller ESP32 is used to integrate all electronic devices into a single environment, ESP32 also has a Wi-Fi module ESP32 has fairly large memory, it uses ESP32 low power It also contains an internal sensor that works with touch, which makes it suitable for use in projects for developing door security systems and motion detection. Designing a smart lab system based on the Internet of Things to solve the problem of wasting energy and preventing unauthorized persons from entering the computer lab without any human intervention, Where the ventilation is activated automatically in the event of a high temperature by opening the windows and the fan, and thus the laboratory has become safe and smart If the windows, door, fan, and lights are left open, the motion sensor senses that there is no movement in the laboratory for a certain time, and it closes the windows, door, fan, and lights automatically.

Figure 2 provides an overview of how a laboratory automation system works Various devices including those that regulate temperature and humidity and open and close doors and windows are controlled remotely via Wi-Fi and a downloaded Android app The digital I/O pins of the Esp32 device are used to connect these Hardware These devices use a communication module known as Esp32 to communicate over a local Wi-Fi network.

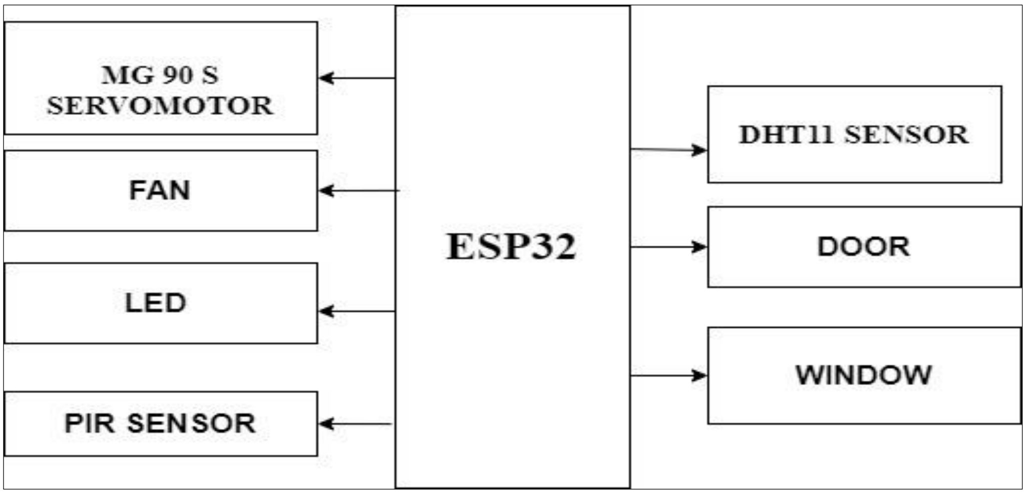

Fig 2: Block diagram of the Smart Lab System using ESP 32

3.1 ESP 32 Development Board

The second set of equipment is placed around the ESP 32 development board and consists of a sensor, a servo motor and a fan, as shown in Figure 2. More details about the components used will be listed as follows:

• ESP 32: The microprocessor sends and receives data to and from the devices.

• DHT11 Sensor: This sensor is a temperature and humidity sensor used to monitor the temperature and humidity inside the lab.

• Fan: This fan will lower the temperature inside the lab to a programmed value.

• MG 90 S Servo Motor: This servo motor is used to open and close the door

A PIR sensor: is an electronic sensor used in motion detectors.

The following flow chart as shown in (3) illustrates the proposed system design of the esp32 controller after connecting it to the lab Wi-Fi network and connecting the wires to the environmental parameters, the sensor senses the temperature of the lab where if the temperature is below 30 it can control the fan to turn on and off and when the DHT11 sensor senses the temperature above 30 degree the fan turns on automatically. Doors and windows can be opened and closed through the mobile application in addition to controlling the lighting and the application records these events and data in the Firebase database.

Fig3: Proposed system Flowchart

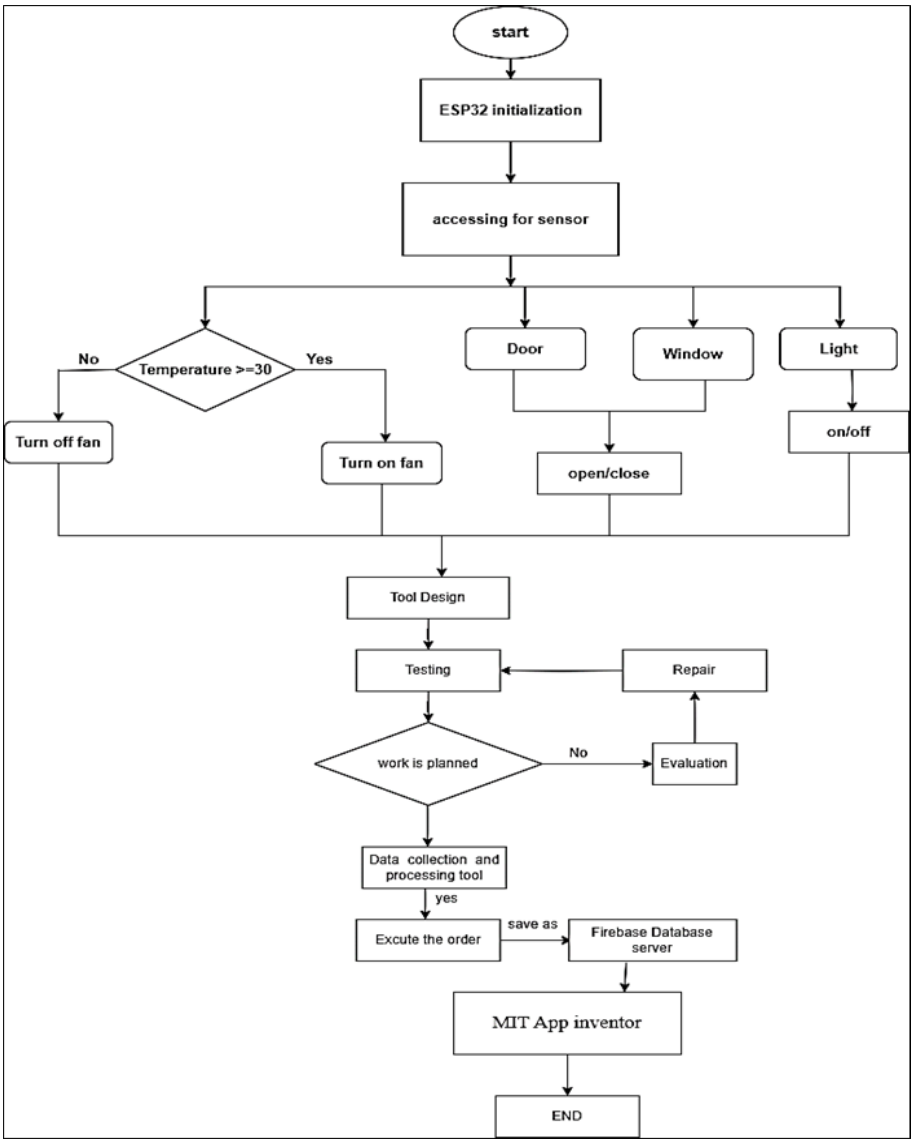

Figure 4 shows a functional model of the proposed system that was designed and tested, and below shows the system that interacts with the ESP32 with the system hardware and sensors, it was implemented on a box about 80 cm long and 50 cm high as shown in Figure5.

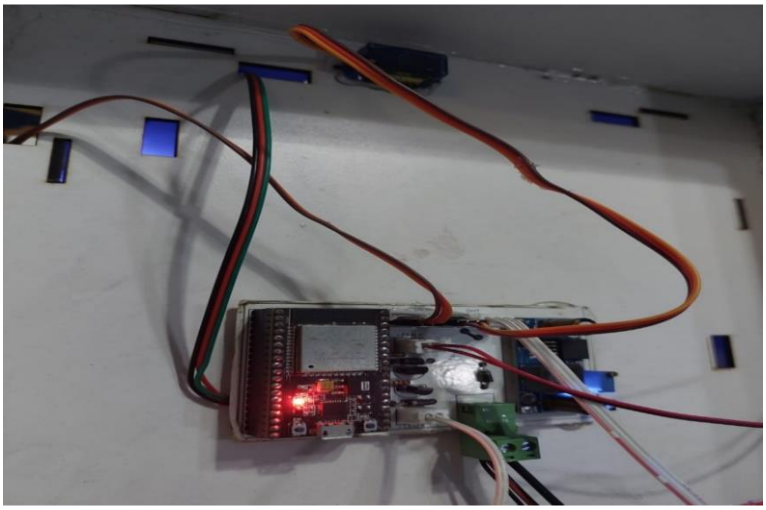

Fig4: The proposed Smart lab Circuit

Fig5.The proposed system designed

The system was tested by conducting a questionnaire consisting of six axes which efficiency project and enhancing the effectiveness of project implementation, application quality and application evaluation in terms of form and compatibility of the application and its clarity with the project and elements of each axis, and sample responses for each axis., which were sent to 30 experts in the field of specialization.

4. RESULTS AND DISCUSSION

The purpose of this study was to explore the potential of IoT technology to enhance laboratory safety and efficiency through IoT networks. To this end, we developed a proposed system that includes temperature and humidity sensors, fan and lighting controls, door and window opening controls, and a motion sensor.

The user needs to install and download the App Inventor software on their laptop or Android phone and after proper installation, they need to create an account in the app to access its services. The first time the app is opened, it will ask you to either login or create an account. The user will be shown the app screen once the setup is complete, the home page will appear and the temperature and humidity will be displayed the user can control the opening and closing of the fan, lighting, door and window, as shown in Figure 6.

Fig6. The proposed application

The following figure 7 shows the implementation of the evaluation results of the IOTS-based intelligent control system for the laboratory, where I integrated, implemented and designed the system, which implemented the operation of the door, window, lighting and fan.

Fig 7. The proposed Smart lab implementation

The following figure (8) shows the fan before and after operation here, you can write the code to operate the fan in the Arduino Uno program and enter the laboratory's Wi-Fi network. The code is uploaded to the microcontroller esp32 and the Wi-Fi network is operated on the smartphone, and you can enter the user interface of the App Inventor application and press the fan button.

Fig 8: shows the fan before and after the operation

The following figure(٩) shows the light before and after the operation here, we write the code to turn on the lighting in the Arduino Uno program, enter the laboratory's Wi-Fi network, the code is uploaded to the controller, turn on the Wi-Fi network on the smartphone, enter the

user interface of the App Inventor application, and press the lighting button.

Fig 9: Lighting appears before and after the operation

The following figure (10) shows the window and door before and after design and implementation, here I write the code for opening and closing the door and window in the Arduino Uno program and enter the laboratory's Wi-Fi network. The code is uploaded to the controller and turns on the Wi-Fi network on the smartphone. Enter the user interface of the App Inventor application and press the door button and the window button, as a mechanism was used to make the door move. And the window

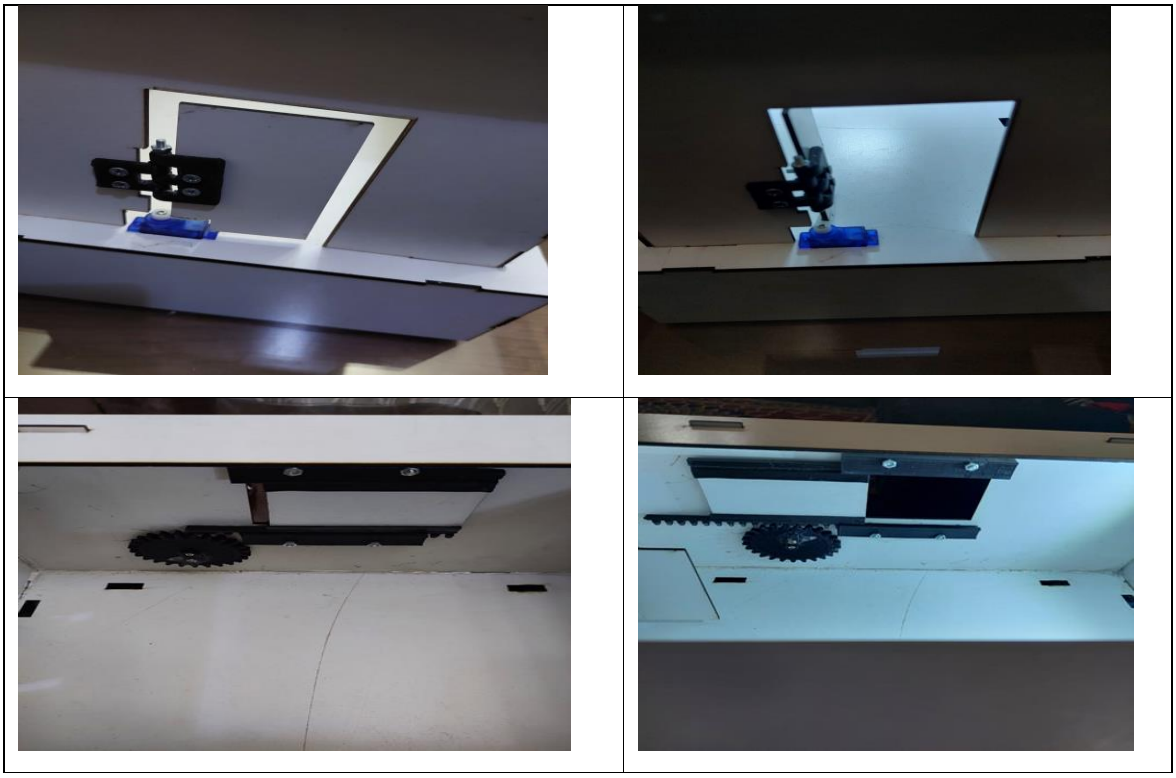

Fig10: shows the window and door before and after the operation

Arduino IDE was used to write programs and upload them to Esp32 compatible boards enter the lab's Wi-Fi network into the Arduino program and also enter it into the App Inventor program and enter the firebase name database into the program code where anything that happens in the application is recorded in the firebase database as shown in Figure 11.

```
void firebase_data() {
  if (Firebase.ready() && signupOK && (millis() - sendDataPrevMillis > 1000 || sendDataPrevMillis == 0)) {
    sendDataPrevMillis = millis();
    // Write an Int number on the database path test/int
    if (Firebase.RTDB.setInt(&fbdo, "/smart_lab/temp", temp)) {
      Firebase.RTDB.setInt(&fbdo, "/smart_lab/hum", hum);
      Serial.println("PASSED");
      Serial.print("temp = "); Serial.println(temp);
      Serial.print("hum = "); Serial.println(hum);
    }
    else {
      Serial.println("FAILED");
      Serial.println("REASON: " + fbdo.errorReason());
    }
```

Fig11: code of smart lab in Arduino IDE

After executing the system operating the components and sensors connected to the esp32 and running the application, these events appear in the Firebase database and the status of the doors, windows and lighting also appears, where operating means true and stopping means false, as shown in Figure 1٢.

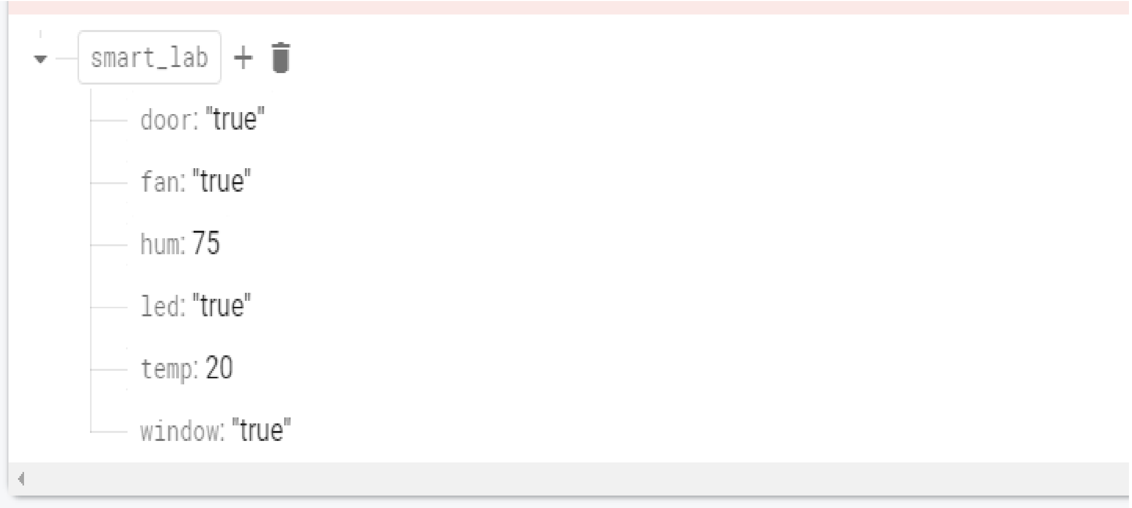

Fig 12. Real-time Firebase database

5. Conclusion

The overall results of the system showed that it is flexible, which increases the motivation of users to use it, the system saves time and effort through the smart laboratory system via mobile and cloud, which increases security and confidentiality by using role-based permissions for users and can be applied in all institutions as it aims to rationalize electricity consumption and also aims to mitigate safety and health risks and the system helped reduce the temperature of computer laboratory equipment, It controlled the lighting of the computer laboratory, the system proved its effectiveness in the event of a rise in the temperature of the computer laboratory, The system proved its quality in recording events in real-time, meaning that any change in the database will be changed immediately in the application Thus, the results proved that the proposed system is simple, effective, and easy to use, manages energy efficiently, and has proven its effectiveness, efficiency, and quality.. In the future, the system can be modified by adding support for phone and Windows Phone users so that more users can access the application.

6. Reference

1. Aldawira, C. R., Putra, H. W., Hanafiah, N., Surjarwo, S., & Wibisurya, A. (2019). Door security system for home monitoring based on ESp32. *Procedia Computer Science*, *157*, 673-682.
2. Abderrahmane, T., Amardjia, N., & Mohammed, T. (2024). Securing laboratories through internet of things networks: a comprehensive approach for ensuring safety and efficiency. Bulletin of Electrical Engineering and Informatics, 13(1), 572-585.
3. Amoran, A. E., Oluwole, A. S., Fagorola, E. O., & Diarah, R. S. (2021). Home automated system using Bluetooth and an android application. Scientific African, 11, e00711.
4. Banagar, A. N., & Khattar, R. (2020). IoT based smart laboratory System. International Journal of Engineering Research & Technology (Ijert) Volume, 9.
5. Poongothai, M., Subramanian, P. M., & Rajeswari, A. (2018, April). Design and implementation of IoT based smart laboratory. In *2018 5th International Conference on Industrial Engineering and Applications (ICIEA)* (pp. 169-173). IEEE.
6. Ghoul, Y., & Naifar, O. (2024). IoT based applications for healthcare and home automation. Multimedia Tools and Applications, 83(10), 29945-29967.
7. Hercog, D., Lerher, T., Truntič, M., & Težak, O. (2023). Design and Implementation of ESP32-Based IoT Devices. Sensors, 23(15), 6739.
8. Jahnavi, T. S., Thumma, N., Reddy, K. A., Teja, U. V., Gunasree, M., & Kiran, M. (2022, August). Health monitoring smart glove using esp32 microcontroller. In Journal of Physics: Conference Series (Vol. 2325, No. 1, p. 012007). IOP Publishing.
9. Mustofa, A. A., Dagnew, Y. A., Gantela, P., & Idrisi, M. J. (2023). SECHA: A Smart Energy-Efficient and Cost-Effective Home Automation System for Developing Countries. Journal of Computer Networks and Communications, 2023(1), 8571506.
10. Odoh, F., Akpomedaye, O., & Ekruyota, O. G. (2023). Design and Development of IoT based Smart System for Monitoring Laboratory Environment. Turkish Journal of Agricultural Engineering Research, 4(2), 263-277.
11. Owojori, A. O., Alade, H. O., &Olotuah, A.O. (2021).Analysis of an Automatic Sliding Window. *Journal of Electrical Engineering, Electronics, Control and Computer Science*, *7*(4), 9-16.
12. Pravalika, V., & Prasad, C. R. (2019). Internet of things based home monitoring and device control using Esp32. International Journal of Recent Technology and Engineering, 8(1S4), 58-62.
13. Tippannavar, S. S., Shivaprasad, N., & Kumar, P. (2022, March). Smart Home Automation Implemented using LabVIEW and Arduino. In 2022 International Conference on Electronics and Renewable Systems (ICEARS) (pp. 644-649). IEEE.
14. Xiao, X. (2024). Smart sensing for laboratory safety management. JOURNAL OF ARTIFICIAL INTELLIGENCE, 1(1), 11-16.
15. Shah, N. H., Khan, D. T., Banu, A. A., & Shah, L. H. (2023). Symmetric and Asymmetric Encryption Schemes for Internet of Things: A Survey. International Journal of Intelligent Systems and Applications in Engineering, 11(1), 254-260
16. Gupta, B. B., & Quamara, M. (2020). An overview of Internet of Things (IoT): Architectural aspects, challenges, and protocols. *Concurrency and Computation: Practice and Experience*, *32*(21), e4946.

نظام مقترح لتعزيز سلامة وكفاءة المختبرات يعتمد على متحكمEsp32

الملخص:

إنترنت الأشياء عبارة عن منصة لأتمتة أنشطة المستخدم في المجتمع بمساعدة الآلات حيث تساعد على تمكين الخدمات المبتكرة من خلال ربط الأشياء المادية والافتراضية والتفاعل الذكي والتواصل بين الآلات حيث لا تزال المراقبة البيئية في المختبرات والعمليات اليدوية موجودة، هناك حاجة إلى الإشراف البشري والعمليات لأداء المهام ، مع التقدم في التكنولوجيا إجراءات العمل ظهرت المختبرات الذكية لتحسين سير العمل في المختبرات وتقليل أحمال العمل على الموظفين داخل المختبر ومن هنا تم إنشاء نظام أتمتة ذكي للمختبر سيقوم النظام بمراقبة التغيرات مثل درجة الحرارة و الإضاءة والتهوية وأنظمة فتح وإغلاق الأبواب والنوافذ تتيح الأتمتة للمستخدم التحكم في المختبر عن بعد من خلال هاتفه وأيضًا من خلال مستشعر الحركة وتحديد الإجراءات التي يجب أن تحدث بناءً على الوقت أو قراءات المستشعر الأخرى مثل الضوء أو درجة الحرارة أو الرطوبة أو التحكم في الأبواب والنوافذ في شبكة الأتمتة، مما يقلل من التدخل البشري وبالتالي استخدام الطاقة بكفاءة وتوفير الوقت والجهد، يعمل النظام المقترح على متحكم Esp32 كوحدة تحكم رئيسية. يربط جميع الأجهزة بالهاتف الذكي من خلال برنامج Arduino IDE وتطبيق MIT app Inventor عبر Wi-Fi.

الكلمات المفتاحية: Esp32- MITappventor- Arduino IDE- Proteus IDE-Sensors -Smart Lab- Firebase