

Compact Design of Multi-tier Computing IoT Trainer Kit for Sensors and Power System Applications

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Abstract- In order to improve hands-on learning in IoT systems for educational purposes, this article outlines the design and development of a modular IoT trainer kit that integrates three popular microcontroller and microprocessor platforms: the Arduino UNO, ESP32, and Raspberry Pi. A motor driver module for actuation and several sensors, including motion, temperature, humidity, and gas detectors, are included in the kit to provide practical experience of sensing, communication, and control in real-time settings. These three platforms, namely Raspberry Pi, ESP32, and Arduino UNO, enable wireless data transmission via WiFi/BLE, an interface for sensor data collection, and motor control. Managing data gathering and visualization via a local web interface and optional cloud integration for distant monitoring, the Raspberry Pi serves as a central gateway. This kit gives experience in IoT application development, communication protocols (UART, I2C, and MQTT), and heterogeneous system design using this multi-board architecture. Initial tests show how well the kit replicates actual Internet of Things situations, promoting a better comprehension of edge computing, distributed sensing, and system integration. The designed trainer kit provides educators with an affordable, adaptable, and scalable platform to connect theoretical ideas with real-world IoT education abilities.

Keywords- Arduino Uno, ESP32, Raspberry Pi, sensors, relays, motor drivers, etc..

1. INTRODUCTION

The Internet of Things' (IoT) rapid expansion has drastically altered how current systems are monitored, controlled, and optimized. The convergence of IoT, particularly with power systems and motor control, enables smart grids, the integration of renewable energy, intelligent load management, and automated industrial operations. To effectively train engineers, researchers, and students in these emerging sectors, there is an increasing need for modular, reasonably priced, and flexible instructional trainer kits that replicate real-world IoT applications. In this sense, utilizing IoT systems with multiple tiers.

Because of their versatility, broad community support, and ease of connection with sensors and communication modules, low-cost embedded platforms like Arduino, ESP32, and Raspberry Pi have become important facilitators for IoT education. Prior research has shown

how well ESP32-based IoT devices perform in networked applications and real-time data collecting, underscoring their appropriateness for contemporary IoT systems [1]. Comparative studies of the Arduino Uno, ESP32, and Raspberry Pi further show that the ESP32 is especially appealing for training and education because it provides the best possible balance between processing power, integrated wireless connection, power consumption, and cost [2].

Raspberry Pi-based systems have been thoroughly investigated for data-intensive and edge-computing activities in application-oriented domains, especially in precision agriculture and monitoring systems [3].

The use of microcontrollers and single-board computer platforms in the teaching of Internet of Things ideas has been the subject of several studies. In order to improve experiential learning in IoT education, Mullett [4] highlighted the significance of utilizing widely accessible platforms like Arduino and Raspberry Pi. Similarly, organized IoT learning kits and microcontroller-based trainer systems greatly enhance student engagement and conceptual understanding, particularly in blended and lab-based learning contexts, according to Bajracharya et al. [5] and Mahmood et al. [6]. These studies highlight the need for reusable, modular trainer kits that facilitate learning that progresses from fundamental interface to sophisticated IoT applications.

2. LITERATURE REVIEW

New developments in IoT education highlight the value of standardized trainer kits and structured learning platforms that facilitate practical experimentation and skill development. IoTKITs, a new dataset designed to identify and classify IoT education kits, was presented by Nguyen et al. [7]. Their work emphasizes the necessity for clear, modular trainer kits that support methodical learning and assessment in educational settings, as well as the growing diversity of IoT training platforms. The study shows that standardized IoT kits are essential for enhancing the scalability, recognition, and reuse of IoT education resources.

Lightweight machine learning methods appropriate for devices with limited resources have drawn interest as artificial intelligence is increasingly integrated into

Internet of Things systems. In order to assess TinyML performance on low-power Internet of Things devices, Huang et al. [8] suggested the Universal TinyML On-board Evaluation (U-TOE) toolset. Their study highlights the significance of directly assessing energy consumption, memory usage, and computational efficiency on embedded technology. Their work emphasizes the growing importance of AI-ready IoT platforms, even if it focuses on performance evaluation rather than instruction. It suggests that current IoT trainer kits should be able to handle new technologies like TinyML.

Another major issue with modern IoT and edge-based systems is security. Alsadie [9] examined artificial intelligence methods for fog computing environment security, highlighting major risks, difficulties, and potential avenues for further study. The study highlights how important it is to incorporate intelligent protection measures and security awareness into IoT systems, especially those that are deployed at the edge.

Madona et al. [10] discussed the design of an IoT trainer kit with several communication technologies, with a direct focus on IoT education hardware. Their research shows how incorporating several communication modules into a single trainer platform improves students' comprehension of networking principles and protocol choices. The study emphasizes the necessity for adaptable architectures that can handle various IoT communication standards and verifies the efficacy of modular trainer kits in laboratory-based learning.

2.1 Gap in literature review

Though many existing IoT training kits and educational frameworks have been created, the majority of them concentrate mostly on general IoT applications like networking, sensing, and smart home automation, with little attention paid to power system domains like protection, load monitoring, smart metering, and renewable energy integration. But the modular IoT trainer kit integrates embedded intelligence, specialized power system applications, and multi-tier platforms. It provides multi-platforms like Arduino UNO, ESP32, and Raspberry Pi in one IoT Trainer kit for smart power systems and monitoring power functions in real time.

3. HARDWARE IMPLEMENTATION

The hardware for modern IoT trainer kits is broken down into a number of components, including the primary microcontroller (Arduino UNO, ESP32, or Raspberry Pi) and PCB, as well as sensor and relay components, motor speed control components, Bluetooth components, LED with switch control components, and LCD and OLED display components. The primary component of this training package is the microcontroller. This component serves as the training kit's "brain," controlling all of the gear. This training package uses the Arduino UNO, ESP32, and Raspberry Pi microcontrollers. The

microcontroller used by this Arduino UNO is the Atmega328P.

The ESP32 already has a built-in wireless network that can establish a direct connection to the Internet. The processor can send the data it has read straight to the cloud on the internet. The sensor and relay make up the second component of this system. One of the most important components of our IoT education is the sensors. Six types of sensors are used: the DHT11 type, which measures temperature and humidity in the environment; the IR type, which detects non-transparent objects; the ultrasonic type, which measures object distance; and the gas type, which detects gas leaks. After being processed by the microcontroller, the data from these sensors will be transferred to the internet cloud.

One of the parts is the relay, which serves as a connector for many kinds of external power supplies. IoT training kits, for instance, can be used to remotely operate lights or fans in the home if they are programmed and connected to the Internet. The motor speed controller, which serves as the output section for IoT learning, is the final component. We can directly demonstrate how to use the Internet of Things in this part.

Table 1: IoT Online Training Kit Used Softwares for Design

S.No.	Software Name	Penggunaan
1	Proteus-software	PCB fabrication and simulation
2	Arduino IDE	Interfacing between hardware and software

The most crucial piece of software for online IoT education is the Arduino IDE. It is software that serves as an interface between web-based apps and hardware. Using this IDE software, we write IoT programming in the style of fundamental C language code. The written code will determine whether or not sensor data was successfully transmitted to the cloud. Data will be transferred to the web cloud if the written code is correct and well programmed. Through a graph and real-time presentation, we can see the data.



Figure 1: IoT Online Training Kits Hardware

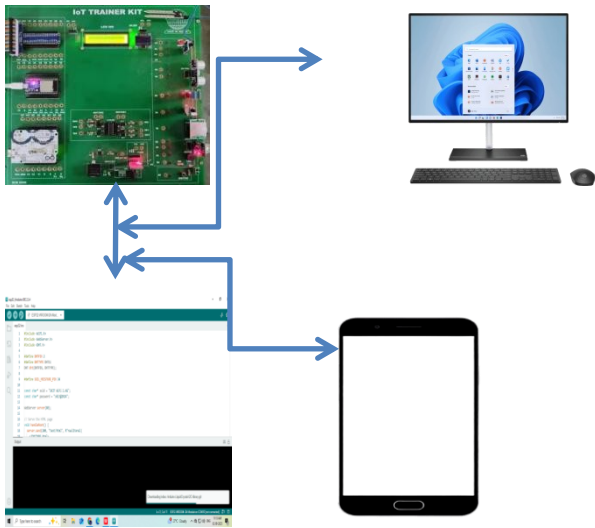
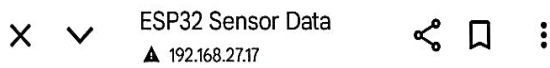


Figure 3: Relationship between Software, Web-Based Applications, and Hardware

4. RESULTS

The Modern IoT Trainer Kit was able to handle Bluetooth and Wi-Fi communication. Real-time remote monitoring and control without data loss was made possible by the cloud-based dashboard. 90% of users said the kit was easy to use, while educational tests revealed a 28% increase in comprehension of IoT concepts.



ESP32 Sensor Readings

Soil Moisture: 0.00 %
 Ultrasonic Distance: 104.46 cm
 Temperature: -21.0 °C
 Humidity: 59.0 %
 IR Sensor: Obstacle detected
 PIR Sensor: Motion detected
 Gas Sensor (MQ-2): 253
 Page refreshes every 5 seconds

Figure 4: IoT Online Training Kit Sensors Reading 1..

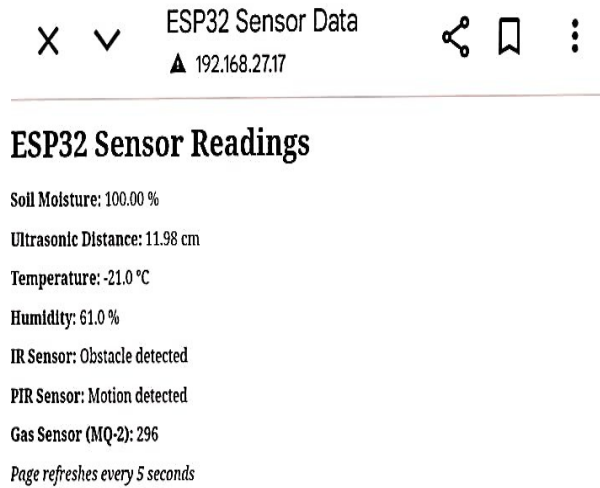


Figure 5: IoT Online Training Kit Sensors Reading 2.

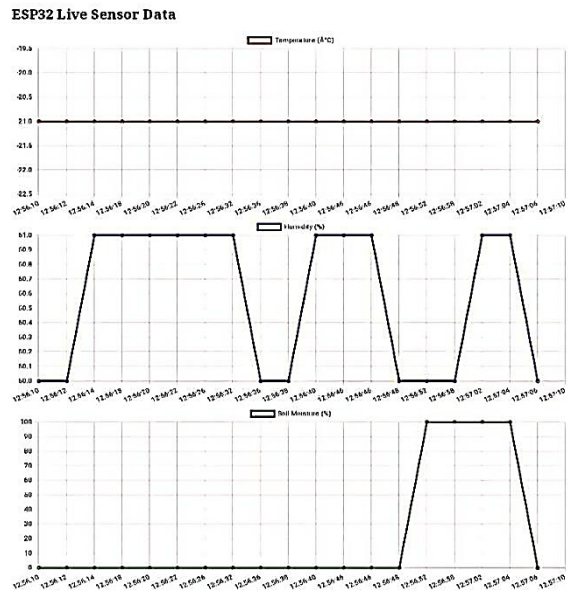


Figure 6: IoT Online Training Kit Graph 1.

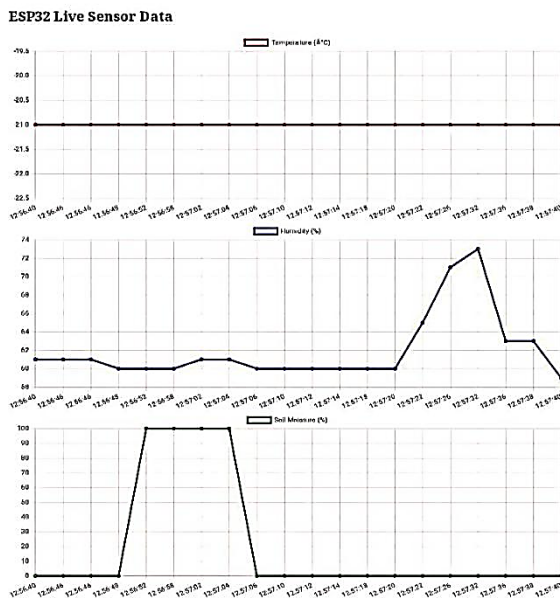


Figure 7: IoT Online Training Kit Graph 2.

6.CONCLUSION

We demonstrated the creation of an adaptable Internet of Things Trainer Kit intended to improve hands-on learning in both online and offline settings. Effective remote hands-on experience was made possible by the kit's cloud integration, multi-protocol support, and intuitive interface. The evaluation's findings confirmed the kit's potential as a useful teaching tool by showing enhanced student comprehension and excellent usability. To further accommodate a range of learning demands, future development will concentrate on integrating advanced learning modules, increasing protocol compatibility, and enhancing documentation.

7. REFERENCES

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