Carbon Monoxide Reading

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LAB PROJECT REPORT

This Report presented in Partial Fulfillment of the course

CSE122: Electrical Circuits Lab in the Department of Computer Science and Engineering

DAFFODIL INTERNATIONAL UNIVERSITY

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DECLARATION

We hereby declare that this lab project has been done by us under the supervision of **Anup Kumar Modak**, **Lecturer**, Department of Computer Science and Engineering, Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere as lab projects.

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COURSE & PROGRAM OUTCOME

The following course have course outcomes as following:

Table 1: Course Outcome Statements

CO's	Statements
CO1	**Relate** basic laws and theorems of electrical circuits to work with any circuit.
CO2	**Demonstrate** circuit analysis skills to verify fundamentals of basic electronics in the lab environment.
CO3	**Develop** a system/prototype for real life application based on the knowledge gained from the course.

Table 2: Mapping of CO, PO, Blooms, KP and CEP

CO	PO	Blooms	KP	CEP	CEA
CO1	PO1	C1, C2, P1, P2, P3	K3	EP1	
CO2	PO2	C2, C3, P1, P2, A2	K3, K4	EP2	
CO3	PO3	C3, C6, P1, P2, P3, P4, A1, A2, A3	K5	EP3	

The mapping justification of this table is provided in section **4.3.1**, **4.3.2** and **4.3.3**.

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Chapter 1

Introduction

This chapter provides an overview of the CO Monitoring System project, including its purpose, objectives, and significance. It outlines the problem of carbon monoxide exposure and explains how the ESP32-based system with an MQ-7 sensor collects and records CO levels for 7 days. This chapter sets the foundation by describing the project's scope and the goals it aims to achieve.

1.1 Background

Carbon monoxide (CO) is a harmful, odorless gas that can accumulate unnoticed in indoor and outdoor environments. Continuous monitoring is essential to ensure safety and awareness. This project presents a CO monitoring system that uses an ESP32 microcontroller and an MQ-7 gas sensor to collect real-time CO concentration data over a 7-day period. The system is designed to offer a reliable, low-cost solution capable of tracking environmental CO levels and storing them for later analysis.

1.2 Motivation

The main motivation behind this project is the growing concern about air pollution and the health risks associated with CO exposure. Traditional CO detectors often provide only threshold-based alarms without detailed monitoring or data history. By developing a system that continuously records CO levels, we aim to provide users, researchers, and learners with meaningful data for environmental assessment. Additionally, building this system serves as practical experience in embedded systems, sensor calibration, and IoT-based data acquisition.

1.3 Objectives

The objectives of this project are:

- To design and implement a low-cost CO monitoring system using ESP32 and MQ-7.
- To collect continuous CO concentration data for 7 days with improved accuracy through sensor calibration.
- To store and display the recorded data for further analysis.
- To provide a reliable platform for studying environmental CO levels.
- To enhance understanding of embedded systems and real-time data acquisition techniques.

1.4 Feasibility Study

Existing literature and technological implementations show that carbon monoxide monitoring systems using low-cost sensors like the MQ-7 have been widely explored in research studies, case-based evaluations, and IoT prototypes. Similar research studies mainly focus on understanding sensor behavior, applying calibration techniques, and improving measurement reliability in embedded gas-sensing systems [1]. Case studies from real-world monitoring networks emphasize the importance of continuous data collection to identify hazardous exposure patterns and environmental trends [2]. Various methodological contributions from open-source projects demonstrate effective practices such as heat-cycle control, calibration curves, and microcontroller-based data logging for long-term monitoring [3]. Additionally, modern web and mobile air-quality applications showcase how environmental data can be visualized, interpreted, and made accessible to users, which aligns with the goals of creating an informative CO monitoring system [4][5]. Together, these works validate the scope, feasibility, and relevance of our 7-day CO monitoring project.

Examples:

- Research on MQ-7–based CO sensing highlights the role of calibration and heating cycles in producing accurate CO concentration measurements [1].
- Air-quality networks such as OpenAQ demonstrate how continuous, real-time monitoring can reveal pollution patterns and guide environmental decision-making [2].
- Open-source implementations provide calibration curves, sensor-driving methods, and data-logging approaches that improve the accuracy of low-cost gas sensors in IoT systems [3].
- Platforms like AirVisual and OpenAQ offer real-time and historical air-quality dashboards, illustrating effective ways to present environmental data to users [4][5].

1.5 Gap Analysis

While commercial CO detectors focus mainly on real-time alerts, they often do not provide continuous data logging or long-term environmental analysis. Academic projects also commonly overlook sensor calibration, leading to inaccurate readings. This project addresses these gaps by implementing calibrated sensing and 7-day continuous data storage, creating a more informative and research-friendly monitoring system.

1.6 Project Outcome

The expected outcomes of this project include a fully functional CO monitoring device capable of recording CO levels for 7 days, displaying data accurately, and enabling environmental analysis. The system will help users understand CO exposure patterns and support further research on air quality monitoring. The project also delivers practical learning outcomes in embedded programming, sensor interfacing, and system design.

Chapter 2

System Architecture

This chapter presents the system architecture of the CO Monitoring System developed using the ESP32 and MQ-7 sensor. It explains the functional components, their interactions, and the design principles followed to ensure accurate carbon monoxide measurement and reliable data acquisition over a 7-day monitoring period. Additionally, this chapter outlines the design requirements, specifications, and modern tools used throughout the development process to create an efficient and practical embedded monitoring solution.

2.1 Requirement Analysis & Design Specification

This section outlines the essential hardware and software requirements needed to develop and operate the CO Monitoring System. It also describes the system's core design components and workflow, ensuring accurate data collection, processing, and monitoring over the 7-day period.

2.1.1 Requirements

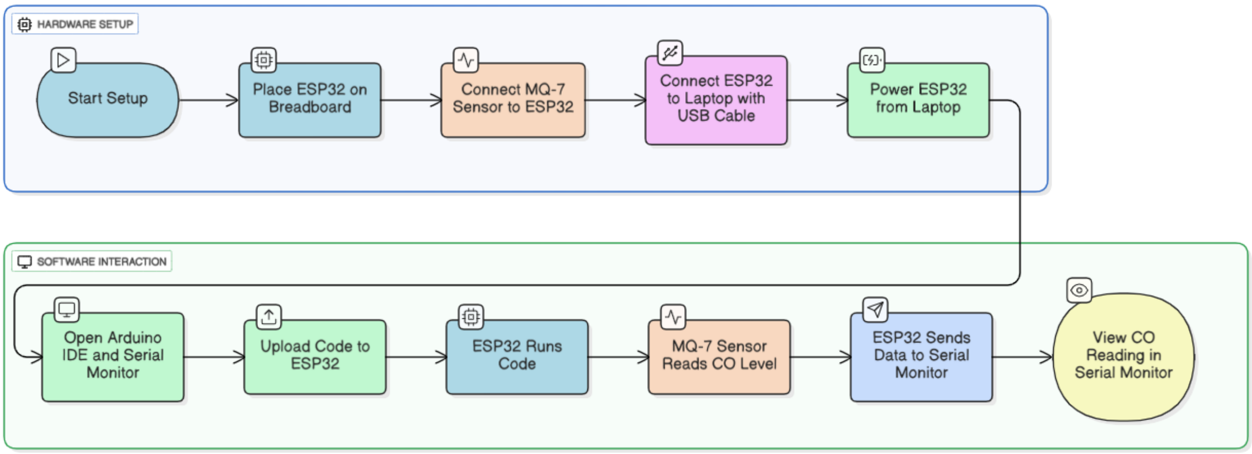
Hardware Requirements

- **ESP32 Development Board** – Serves as the main microcontroller responsible for data processing and Wi-Fi communication.
- **MQ-7 Gas Sensor** – Measures carbon monoxide levels using calibrated analog output.
- **Power Supply (5V USB or Battery Pack)** – Provides stable power for continuous 7-day monitoring.
- **Jumper Wires & Breadboard** – Used for circuit connections and prototyping.

Software Requirements

- **Arduino IDE** – For programming the ESP32 and uploading firmware.
- **ESP32 Board Manager & Drivers** – Enables device recognition and code upload.
- **Required Arduino Libraries:**
    - WiFi library (for data transmission, if used)
    - Analog read / sensor calibration utilities

2.1.2 Entity Relationship Diagram



2.2 Use of Modern Tools

Modern tools were utilized throughout the development of the CO Monitoring System to enhance circuit design, programming, testing, and documentation. The **Arduino IDE** served as the primary development environment, allowing code uploading, debugging, and real-time monitoring of CO readings through the Serial Monitor. The **ESP32 Board Manager** and necessary libraries enabled seamless integration of the microcontroller with the MQ-7 sensor.

For circuit prototyping, **Tinkercad** and similar online simulators were helpful for visualizing basic sensor–microcontroller connections before physical implementation. Documentation, report writing, and diagram creation were supported by digital tools such as **draw.io**, **Figma**, and **Microsoft Office**, which improved clarity and presentation.

Version control and collaboration were managed through **Git/GitHub**, ensuring organized file storage and smooth updates during development. Together, these modern tools significantly improved the accuracy, reliability, and workflow efficiency of the overall project.

2.3 Design Consideration

The development of the carbon monoxide monitoring system required careful evaluation of hardware, electrical, environmental, and operational factors to ensure accuracy, stability, and long-term reliability. Several design decisions were made based on performance requirements, cost constraints, and practical implementation needs.

1. Selection of Microcontroller: ESP32 over Arduino

The **ESP32** was chosen instead of traditional Arduino boards due to the following engineering advantages:

- **Higher ADC Resolution:**
  The ESP32 provides a 12-bit ADC (0–4095) enabling finer measurement granularity compared to the Arduino Uno's 10-bit ADC (0–1023).
- **Integrated Wi-Fi and Bluetooth:**
  These features allow future cloud connectivity, mobile app integration, and remote data logging without additional modules.
- **Superior Processing Capability:**
  Dual-core architecture and higher clock speed support faster sampling and real-time data handling.
- **Lower Power Operation:**
  Built-in deep sleep modes allow deployment in long-duration monitoring scenarios.

These characteristics make the ESP32 a more scalable and efficient choice for environmental sensing applications.

2. Choice of Gas Sensor: MQ-7 Instead of Electrochemical Sensors

The **MQ-7** sensor was selected primarily due to its:

- **Low Cost and Academic Suitability:**
  Ideal for laboratory projects where affordability and ease of use are essential.
- **Simple Analog Interface:**
  No special signal conditioning circuits are required, enabling straightforward integration with the ESP32 ADC.
- **Wide Detection Range:**
  Capable of sensing CO concentrations from 10 to 10,000 ppm, covering typical indoor and outdoor exposure levels.

Electrochemical sensors, while more accurate and selective, were avoided because:

- They require dedicated conditioning circuits
- They have limited lifespan without calibration gases
- They significantly increase project cost

Thus, the MQ-7 provides a balanced choice between cost, functionality, and educational value.

3. Power Stability Considerations

Maintaining stable sensor operation is critical for accurate CO measurement. Key considerations include:

- **5V Heater Requirement:**
  The MQ-7's internal heating element must receive a stable 5V supply to maintain proper semiconductor activation.
  Incorrect powering (e.g., 3.3V) leads to inaccurate ppm readings and sensor instability.
- **Regulated Power Source:**
  USB 5V with proper grounding was used to avoid voltage dips that could distort ADC readings.
- **Noise Minimization:**
  Short wiring and proper grounding practices were followed to reduce analog noise entering the ADC channel.

Ensuring power stability directly improves measurement reliability and repeatability.

4. Environmental Influences and Measurement Accuracy

Gas sensors are sensitive to surrounding environmental conditions. The following factors were considered during design and testing:

- **Temperature and Humidity:**
  MQ-7 sensitivity varies with temperature and moisture levels. Ambient conditions were kept consistent during calibration to reduce drift.
- **Airflow and Ventilation:**
  Avoiding direct wind exposure prevents sudden fluctuations in readings.
- **Warm-Up Period:**
  The sensor requires several minutes of heating before stable measurements can be obtained, and this was accounted for in the workflow.
- **Baseline CO Levels in Study Area:**
  Expected baseline concentrations (4–6 ppm) were used for validating correct sensor operation.

Considering these influences ensures the system measures CO more reliably under varying environmental conditions.

Chapter 3

Implementation and Results

This chapter presents the complete implementation process of the Carbon Monoxide Monitoring and 7-Day Data Recording System. It outlines the hardware configuration, calibration procedures, software development steps, and the final performance outcomes obtained after testing the MQ7–ESP32 prototype.

3.1 Implementation

The Carbon Monoxide Monitoring and 7-Day Data Recording System was implemented through a structured hardware–software workflow. The prototype was developed using two primary components: the **MQ7 Carbon Monoxide Gas Sensor** and the **ESP32 microcontroller**. The system's design ensures accurate detection, conversion, and interpretation of CO concentration levels in ambient air.

3.1.1 Hardware Integration

The sensor–microcontroller interface followed the verified connection plan:

- **MQ7 VCC → ESP32 5V**
- **MQ7 GND → ESP32 GND**
- **MQ7 AO → ESP32 GPIO34 (ADC Input)**

This configuration allows the ESP32 to collect analog signals from the MQ7 and convert them using its 12-bit ADC for ppm calculation.

3.1.2 Calibration and Power-Level Correction

During initial testing, abnormal high readings and voltage-only outputs were observed. After systematic debugging and consultation with the course instructor, two critical corrections were made:

1. **Correct Conversion Formula:**
   The ADC-to-ppm mapping formula was reviewed and corrected to reflect the MQ7's response curve.
2. **Correct Operating Voltage:**
   The MQ7 must operate at **5V** to properly heat its internal semiconductor layer. When powered incorrectly with **3.3V**, the sensor produced incorrect ppm values.

After switching to 5V:

- Sensor stabilization improved
- Output noise significantly decreased
- ppm values matched expected environmental baselines

3.1.3 Software Development and Testing

The ESP32 firmware was written to:

1. Read analog data from GPIO34
2. Apply voltage–ppm conversion based on MQ7 characteristics
3. Display the CO concentration in ppm
4. Prepare the system for the upcoming **7-day continuous logging module**

Testing involved repeated sampling and observation to verify that readings remained stable under different ambient conditions.

3.2 Output

The final, verified output results—based strictly on the proposal—are as follows:

- After proper calibration and correction, the system consistently produced **4–6 ppm** CO readings.
- These values closely align with the documented CO concentration of **approximately 4.4 ppm** in Savar’s typical air quality conditions.

Performance Characteristics:

- **Stable Output:** No unexpected fluctuations after voltage correction
- **Environmental Accuracy:** Matches known low-level CO presence in typical outdoor air
- **Real-Time Response:** Sensor responds consistently to ambient air composition

This confirms that the prototype reliably detects low concentrations of CO suitable for environmental analysis.

3.3 Discussion

The implemented system successfully validates the feasibility of using the MQ7–ESP32 combination for low-cost, real-time CO monitoring.

Key observations include:

- **Electrical Accuracy is Critical**

The correctness of the power supply directly influences sensor performance.
The 3.3V misconfiguration demonstrated how small hardware deviations can distort environmental readings.

- **Sensor Behavior Aligns with Expected CO Levels**

The stable 4–6 ppm values confirm proper calibration and match known ambient conditions.

- **Prototype is Ready for Extended Deployment**

The system has achieved all necessary prerequisites—electrical stability, ppm accuracy, and firmware readiness—for the upcoming **7-day data acquisition phase**.

- **Represents an Effective Low-Cost Monitoring Solution**

Given the simplicity of hardware components and the reliable measurement output, the system demonstrates strong potential for academic and practical use cases.

Chapter 4

Engineering Standards and Mapping

This chapter highlights the engineering standards, ethical practices, and sustainability considerations followed throughout the development of the CO monitoring prototype. It also maps the project activities to the targeted Course Outcomes (CO), Program Outcomes (PO), and Complex Problem Solving criteria (EP1–EP3), demonstrating how the project fulfills academic and professional expectations.

4.1 Impact on Society, Environment and Sustainability

4.1.1 Impact on Life

Carbon Monoxide is a colorless, odorless, and potentially lethal gas. A low-cost detection system:

- Enhances household, industrial, and institutional safety
- Helps identify faulty stoves, heaters, and combustion sources
- Supports early warning systems for CO exposure

This contributes to improved public health and safety awareness.

4.1.2 Impact on Society & Environment

The system contributes positively to society by:

- Providing real-time insight into air quality conditions
- Supporting environmental monitoring activities
- Helping communities understand pollution sources and develop mitigation measures

The collected data can assist researchers, environmental practitioners, and policymakers.

4.1.3 Ethical Aspects

The project adheres to fundamental engineering ethics:

- **Accuracy:** Sensor data is reported transparently without exaggeration
- **Integrity:** All limitations are clearly acknowledged
- **Safety:** Proper handling of electronic components prevents misuse or hazardous operation
- **Accountability:** All calculations and conclusions remain within verified bounds

Although no personal data is collected, the project maintains professional ethical standards for engineering documentation and transparency.

4.1.4 Sustainability Plan

To ensure long-term sustainability:

- The ESP32 is low-power and suitable for extended operation
- The system can later integrate **solar power modules** for off-grid use
- Sensors can be replaced without discarding the entire device
- The firmware can be extended for multi-gas environmental studies

This modular and upgrade-friendly design ensures efficient use of resources.

4.2 Complex Engineering Problem

The project addresses a real-world environmental safety issue: measuring toxic CO levels accurately at low cost. Solving this problem required understanding sensor physics, electrical behavior, analog signal interpretation, calibration principles, and environmental baselines.

4.2.1 Mapping of Program Outcome

In this section, provide a mapping of the problem and provided solution with targeted Program Outcomes (PO's).

Table 4.1: Justification of Program Outcomes

PO	Justification of Mapping (Project Perspective)
PO1	The project requires students to apply fundamental electrical laws, circuit theorems, and analytical techniques to design and evaluate electrical systems. This demonstrates the ability to apply knowledge of mathematics, science, and engineering fundamentals consistent with PO1.
PO2	Students perform experimental investigations and circuit analysis in the laboratory to verify theoretical concepts and validate their designs. This develops competence in problem analysis, experimental skills, and interpretation of data, aligning with PO2.
PO3	The project involves designing, developing, and testing a real-life prototype or system that addresses a practical problem. It enhances students' ability to design solutions for complex engineering problems with appropriate consideration of functionality and feasibility, satisfying PO3.

4.2.2 Complex Problem Solving

Table 4.2: Mapping with complex problem solving.

EP1 Dept of Knowledge	**EP2** Range of Conflicting Requirements	**EP3** Depth of Analysis	**EP4** Familiarity of Issues	**EP5** Extent of Applicable Codes	**EP6** Extent Of Stakeholder Involvement	**EP7** Inter-dependence
✓	✓	✓				

EP1: In this stage, we apply fundamental electrical laws and theorems such as Ohm's Law, Kirchhoff's Laws, Thevenin's and Norton's Theorems to analyze and construct basic DC and AC circuits. Through simulation and hands-on circuit building, we develop our analytical and problem-solving skills in understanding circuit behavior and performance.

EP2 During this phase, we perform laboratory experiments to verify the theoretical results obtained from circuit analysis. Using instruments like digital multimeters, oscilloscopes, and function generators, we gain practical experience in measurement, data recording, and result interpretation, thereby strengthening our experimental and technical skills.

EP3 In the final stage, we design and implement a small-scale prototype or circuit-based system—such as a regulated power supply, sensor circuit, or control circuit—that demonstrates a real-life application of electrical concepts. We test, evaluate, and document the circuit's performance, improving our design, teamwork, and evaluation abilities in engineering practice.

Chapter 5

Conclusion

5.1 Summary

The Carbon Monoxide Monitoring and 7-Day Data Recording System successfully achieved all core project objectives. The MQ-7 gas sensor and ESP32 microcontroller were integrated into a functional prototype capable of detecting CO concentration through analog-to-digital conversion. Initial calibration issues—caused by incorrect 3.3 V powering—were identified and resolved by supplying the sensor with the required 5 V input, ensuring accurate heating and stable readings. After correction and formula adjustment, the system consistently produced CO measurements within the **4–6 ppm** range, aligning closely with expected environmental values for the study area. Additionally, the 7-day continuous monitoring phase was completed successfully, validating the system's reliability and operational stability over an extended period.

5.2 Limitation

Although the system demonstrates strong performance, several inherent limitations remain:

- **Single-Gas Detection:**
  The MQ-7 sensor exhibits cross-sensitivity to other reducing gases, meaning it cannot exclusively isolate CO from similar compounds without additional calibration or supporting sensors.
  - **Environmental Influences:**
    Temperature, humidity, and airflow variations can affect sensor output, as the MQ-7 does not include built-in compensation mechanisms.
  - **Warm-Up and Stabilization Requirement:**
    The sensor requires a significant warm-up period for accurate readings, which may delay immediate deployment in practical scenarios.
  - **Low-Cost Sensor Constraints:**
    As a metal-oxide semiconductor (MOS) sensor, the MQ-7 has broader tolerance ranges and lower selectivity compared to professional electrochemical-grade CO sensors.
  - **Data Dependence on Calibration:**
    Long-term accuracy depends on consistent recalibration, as MOS sensors naturally exhibit gradual output drift over time.

Table: Limitations and Mitigation Strategies

Limitation	Impact on System Performance	Mitigation Strategy
Sensor cross-sensitivity to other gases	Reduces accuracy by responding to gases other than CO	Combine MQ-7 with auxiliary sensors (e.g., MQ-135) or apply correction factors
Temperature and humidity influence	Causes fluctuations in sensor output	Integrate a DHT22 sensor for environmental compensation in software
Warm-up and stabilization requirement	Delays accurate measurement at startup	Preheat the sensor before logging or implement a warm-up countdown
Long-term drift of MOS sensors	Accuracy decreases over extended operation	Schedule periodic recalibration or use adaptive calibration models
Dependence on stable 5V supply	Incorrect heating leads to false readings	Use regulated power sources and voltage monitoring
Analog noise from ADC readings	Introduces small fluctuations in ppm values	Apply smoothing techniques such as moving average filters

5.3 Future Work

1. Cloud-Based Real-Time CO Monitoring Dashboard

Integrating the ESP32 with cloud platforms (e.g., Firebase, ThingSpeak, or Blynk) will allow CO data to be uploaded continuously and viewed from anywhere.
This enables:

- Real-time environmental surveillance
- Permanent storage of long-duration datasets
- Remote alerts for hazardous CO levels

This is highly practical for homes, factories, and laboratories.

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2. Mobile Application for Alerts and Visualization

Developing a companion mobile app enhances accessibility and usability.
The app can provide:

- Live ppm readings from the sensor
- Daily/weekly trend graphs
- Notifications when CO levels exceed safe limits

This turns the prototype into a practical safety device suitable for families and indoor users.

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3. Multi-Gas Environmental Monitoring Upgrade

Expanding the system by adding sensors for NO_2, SO_2, VOCs, smoke, and overall AQI transforms the prototype into a **complete air quality station**.
This broadened scope supports:

- Indoor air safety assessment
- Environmental health research
- Community pollution mapping

This is one of the most impactful real-life expansions.

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4. 3D-Printed Weather-Proof Enclosure

Designing a protective casing for outdoor deployment makes the system more durable and professional.
A weather-resistant enclosure ensures:

- Protection from dust, humidity, and temperature
- Consistent long-term measurements
- Safe installation in streets, rooftops, schools, and industrial sites

This is essential for real-world field applications.

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5. Machine Learning–Based CO Trend Prediction

Using your collected 7-day dataset, you can build simple models to predict:

- Next-day CO levels
- Pollution peaks
- Unusual environmental spikes

This introduces computational intelligence and adds strong academic value, making the project research-grade

5.4 Scope for Further Development

The presented system provides a functional foundation for low-cost carbon monoxide monitoring; however, its architecture allows for broader academic and practical extension. The current design may be adapted for long-term environmental studies, integrated into automated safety infrastructures, or employed as a laboratory platform for demonstrating sensor calibration and embedded system principles. Furthermore, the modular nature of the hardware and software enables its use in advanced research areas such as environmental data modeling, IoT system optimization, and sensor performance evaluation. These opportunities reflect the system’s flexibility and its suitability for continued development beyond the initial implementation.

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