AEEJ : Journal of Automotive Engineering and Vocational Education

Volume: 06, Number: 01, 2025
ISSN: 2722-4031 [online]; 2722-404X [printed]
DOI: https://doi.org/10.24036/aeej.v6i1.270

Design of IoT-based Vehicle Cabin Temperature and Humidity Data Acquisition System

Muhammad Ridwan[1]*, Wawan Purwanto[1,2], Hendra Dani Saputra[1], M. Yasep Setiawan[1,2], Joel O. Abratiguin[3]

Abstract

The rising temperature of vehicles in parking lots under the sun is a major cause of poisoning caused by harmful gases in the blood, and the most toxic gas is ammonia (NH3). Exposure to high concentrations of ammonia gas can cause lung damage and death. This research aims to design and build an Internet of Things (IoT)-based vehicle temperature monitoring system using the DHT11 sensor. The DHT11 sensor is able to detect temperature and humidity in real-time with a sufficient level of accuracy, one of the main objectives in the acquisition of temperature data in the vehicle cabin is to improve passenger comfort. Temperatures that are too high or too low can reduce ride comfort. One of the main objectives in the acquisition of temperature data in the vehicle cabin is to improve passenger comfort. Temperatures that are too high or too low can reduce ride comfort. By monitoring and controlling the temperature in the cabin in real-time, the cooling (air conditioning) and heating systems can function more efficiently to maintain the optimal temperature.

Keywords
NodemCU, DHT11, Google Spreadsheet, Thermocouple

[1]Automotive Engineering Department, Universitas Negeri Padang
Prof. Dr. Hamka Street, Air Tawar, Padang, West Sumatera, Indonesia
[2]Research Center for Energy Efficient Cars (PRIME)
Prof. Dr. Hamka Street, Air Tawar, Padang, West Sumatera, Indonesia
[3]University of Science and Technology of Southern Philippines
Alubijid, Misamis Oriental, Philippines
**Muhammadridwanprm@gmail.com*

Submitted : March 24, 2025. Accepted : May 28, 2025. Published : June 30, 2025

INTRODUCTION

An increase in vehicle cabin temperature while parked under direct sunlight is a major factor contributing to toxic gas accumulation in the blood, which can lead to oxygen deprivation. One of the most dangerous gases involved in this process is ammonia (NH_3) [1]. Technological advancements across various aspects of human life have progressed rapidly, as evidenced by the proliferation of sophisticated tools designed to simplify human tasks. In line with growing demands, one of the prominent technological developments today is the Internet of Things (IoT). IoT is among the most recent global technologies and is expected to become increasingly prevalent in the future. It enables physical devices—such as temperature, humidity, and other sensors—to connect to the internet, allowing users to monitor and control them remotely via smartphones [2]. Temperature and humidity must be maintained within specific thresholds to ensure reproducibility, reduce long-term modification costs, and meet precision requirements. The application of IoT concepts has been widely explored in various fields, including air quality monitoring and notification systems, power management systems, smart homes, smart greenhouses, and numerous other real-time control and monitoring solutions that make tasks more efficient and manageable [3].

NodeMCU is an open-source Internet of Things (IoT) platform that was initially developed using the ESP8266 microcontroller and has since been extended to include a more advanced version utilizing the ESP32. The NodeMCU ESP32 presents notable advancements compared to its predecessor, featuring a dual-core CPU, built-in Wi-Fi and Bluetooth functionalities, and an increased quantity of I/O pins for connecting sensors and actuators [4]. In contrast to the ESP8266, which is limited to Wi-Fi connectivity, the ESP32 offers additional functionalities, including power-saving modes and improved security features, such as secure boot and flash encryption. The device includes a USB serial interface, facilitating straightforward programming via a USB cable without requiring extra hardware. This characteristic renders it particularly suitable for the development of IoT applications necessitating wireless connectivity and enhanced processing capabilities.

The DHT11 is a digital sensor that provides calibrated measurements of temperature and humidity. This component is cost-effective, demonstrating good stability and reliable calibration accuracy. The calibration coefficients are retained in a one-time programmable (OTP) memory, allowing the internal sensor module to integrate these coefficients into its measurement computations. The sensor can transmit signals over a distance of up to 20 meters. The device functions at a supply voltage of +5V, measuring temperature from 0 to 50°C with an accuracy of ±2°C, and humidity from 20% to 90% RH with an accuracy of ±5%. The DHT11 employs a digital interface for data transmission to microcontrollers, including Arduino and NodeMCU, with a data output frequency of approximately one second. The DHT11, although less accurate than alternatives like the DHT22, is appropriate for low-cost applications that necessitate basic temperature and humidity monitoring, such as home automation, smart agriculture, and environmental sensing systems. Accurate measurements require adherence to established measurement standards. The instruments utilized must adhere to these standards, and the methods applied must meet technical requirements. Users must comprehend the quantity being measured, the suitable measurement techniques, and the correct units of measurement [5].

Temperature and Humidity Measurement Components

1. Arduino Uno Microcontroller

A microcontroller is an integrated circuit (IC) that contains a microprocessor, read-only memory (ROM), and general-purpose random-access memory (RAM). Microcontrollers are compact, cost-effective, and widely used in systems that do not require complex computations, such as basic embedded applications. One of the most used microcontrollers is the Arduino [6].

Arduino, as depicted in Figure 1, constitutes an open-source electronics platform that integrates user-friendly hardware and software components. The system accommodates multiple sensors for environmental condition detection and actuators, including lights and motors. Various Arduino variants are available, such as the Arduino Uno, Arduino Mega 2560, and Arduino Fio. The Arduino Uno utilizes the ATmega328 microcontroller and includes 14 digital input/output pins, of which 6 support PWM output, alongside 6 analog inputs, a 16 MHz crystal oscillator, a USB port, a power jack, an ICSP header, and a reset button. The Arduino board facilitates straightforward connectivity to a computer through USB for programming and data exchange.

Figure 1. Arduino board [6]

2. NodeMCU 32s

NodeMCU is an open-source Internet of Things (IoT) platform that was initially developed using the ESP8266 microcontroller and has since been extended to include a more advanced version utilizing the ESP32. The NodeMCU, built on the ESP32 platform, presents notable improvements compared to its predecessor, featuring a dual-core CPU, integrated Wi-Fi and Bluetooth capabilities, and an increased number of I/O pins for sensor and actuator connections. In contrast to the ESP8266, which is limited to Wi-Fi connectivity, the ESP32 offers advanced capabilities, including low-power operation modes and improved security features such as secure boot and flash encryption [7]. The board includes an integrated USB-to-serial interface, facilitating straightforward programming through a USB cable, eliminating the need for external programming hardware, as shown in Figure 2. The NodeMCU ESP32 exhibits characteristics that render it an optimal platform for the development of wireless, high-performance IoT applications.

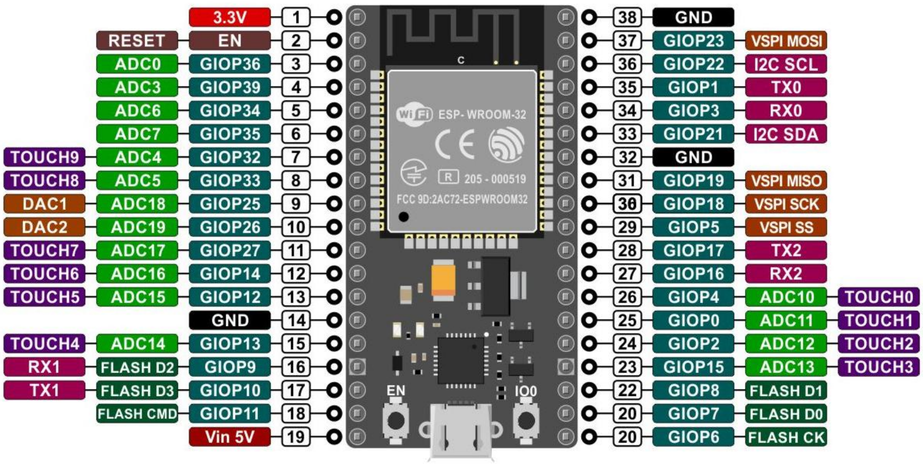

Figure 2. NodemCu

3. DHT11

The DHT11 sensor is a digitally calibrated component capable of providing temperature and humidity data. It is known for its high stability and reasonably accurate calibration capabilities. The calibration coefficients are stored in a one-time programmable (OTP) memory, allowing the internal sensor module to incorporate these coefficients into its measurement calculations. This enables signal transmission over a range of up to 20 meters [8]. The DHT11 operates at a supply voltage of +5V, with a temperature measurement range of 0 to 50°C and an accuracy of ±2°C. For humidity, it measures within the range of 20% to 80% RH with an accuracy of ±5%. The sensor uses a digital interface to transmit data to microcontrollers such as Arduino or NodeMCU and is capable of outputting data at approximately one-second intervals. Although its accuracy is lower than that of more advanced sensors such as the DHT22, the DHT11 is well-suited for applications requiring low-cost, easy-to-use solutions for measuring temperature and humidity. These include home automation systems, smart agriculture, and environmental monitoring.

4. Conceptual Framework

In this study, the system workflow begins with the “Start” phase, which marks the initiation of the device development process, as described in Figure 3. The initial stage of this process is the “Design and Realization” phase, which involves conceptual planning, component selection, and device assembly aligned with the specified objectives. Upon completion of the design and realization phase, the process advances to the "Device Configuration" stage, which entails the adjustment of hardware and software parameters to achieve optimal performance. Upon successful execution of the configuration, the subsequent phase is "Device Testing," during which the system undergoes evaluation to confirm its functionality aligns with the design specifications. Upon confirmation of effective operation during the testing phase, the process advances to the “Finish” phase, signifying the device's readiness for deployment. Should any errors or malfunctions be identified during testing, the process reverts to the design and realization stage for required corrections. The iterative process persists until the device demonstrates reliable performance and satisfies operational standards. This framework offers a structured overview of system development, encompassing the stages of design, configuration, and testing, alongside ongoing evaluation to guarantee optimal functionality prior to final implementation.

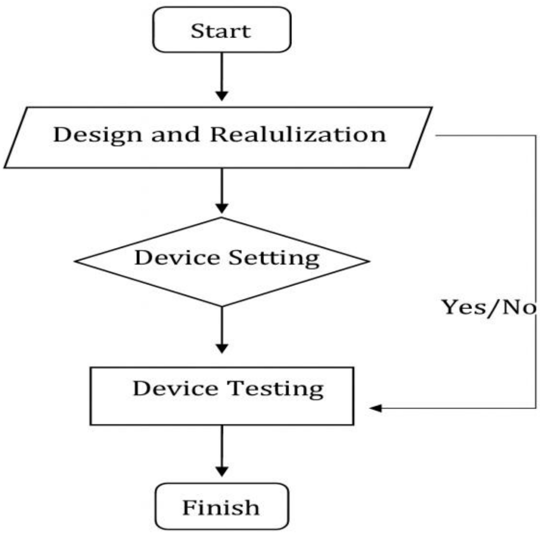

Figure 3. Conceptual Framework diagram

METHOD

Research Design

This study's research design delineates a systematic sequence of steps to be executed methodically. This study utilizes an experimental approach within the context of research and development (R&D) methodology [9]. The R&D approach is characterized as a systematic process designed to identify, formulate, improve, develop, produce, and assess the effectiveness of a specific product, model, method, strategy, or service. This study implements the R&D method through several essential stages, starting with the design and development of an initial system prototype based on predetermined design specifications. Subsequently, field testing occurs, during which the system is assessed in real-world conditions and adjusted based on performance feedback and evaluation results [10]. The following stages include validating the system's reliability and functionality, scaling the system implementation, and disseminating the research findings. The proposed in-vehicle temperature and humidity data acquisition system is systematically constructed by following these development phases, ensuring optimal performance in accordance with user requirements and practical field conditions.

In this study, the development focuses on designing an IoT-based temperature and humidity monitoring system using NodeMCU and DHT11 sensors. These components are selected due to their affordability, simplicity, and effectiveness. The system collects real-time data and transmits it to the cloud via Wi-Fi, enabling remote and local monitoring. Through periodic data collection, users can track environmental changes inside the vehicle cabin both when the car is parked and in motion. This continuous monitoring ensures a comprehensive understanding of thermal conditions, supporting a reliable and user-oriented system.

Block Diagram

This study illustrates the system design using a block diagram, as depicted in Figure 4, offering an overview of the interactions among components within the overall architecture. This diagram serves as a visual representation of the logical flow and integration among all subsystems, ensuring cohesive performance of the tool when fully assembled and operational. The DHT11 sensor serves as the primary component of the system, measuring ambient temperature and humidity within the vehicle cabin. The sensor acquires environmental data and functions as the main input device within the system. The data is subsequently transmitted to the NodeMCU ESP8266, which serves as the primary controller. The NodeMCU, programmed with the Arduino IDE, processes incoming signals and enables wireless data transmission through its integrated Wi-Fi module. The sensor data can be transmitted in real time to cloud-based platforms for storage and monitoring through this mechanism.

These components form an integrated system that facilitates the efficient acquisition, processing, and remote access of temperature and humidity data. The block diagram functions as both a technical blueprint and a strategic visualization of the system's functionality and connectivity.

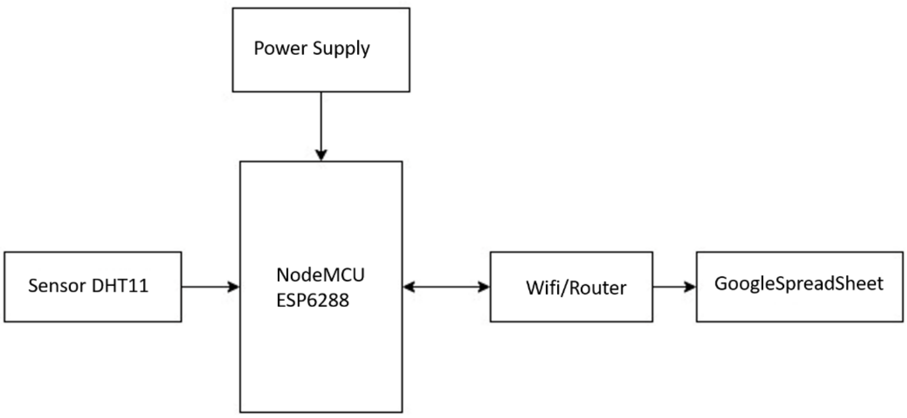

Figure 4. Block diagram

Preliminary Hardware Design

The system schematic presented in Figure 5 depicts the design of a temperature and humidity monitoring system, comprising four sensors—Sensor 1 to Sensor 4—utilizing KY-015 modules that incorporate the DHT11 sensor. The sensors interface with a NodeMCU ESP32 microcontroller and are powered by a battery via a PCB (Printed Circuit Board) configuration. The diagram clearly labels each sensor: Sensor 1, Sensor 2, Sensor 3, and Sensor 4. All sensors operate as temperature and humidity input units utilizing the DHT11 sensing element.

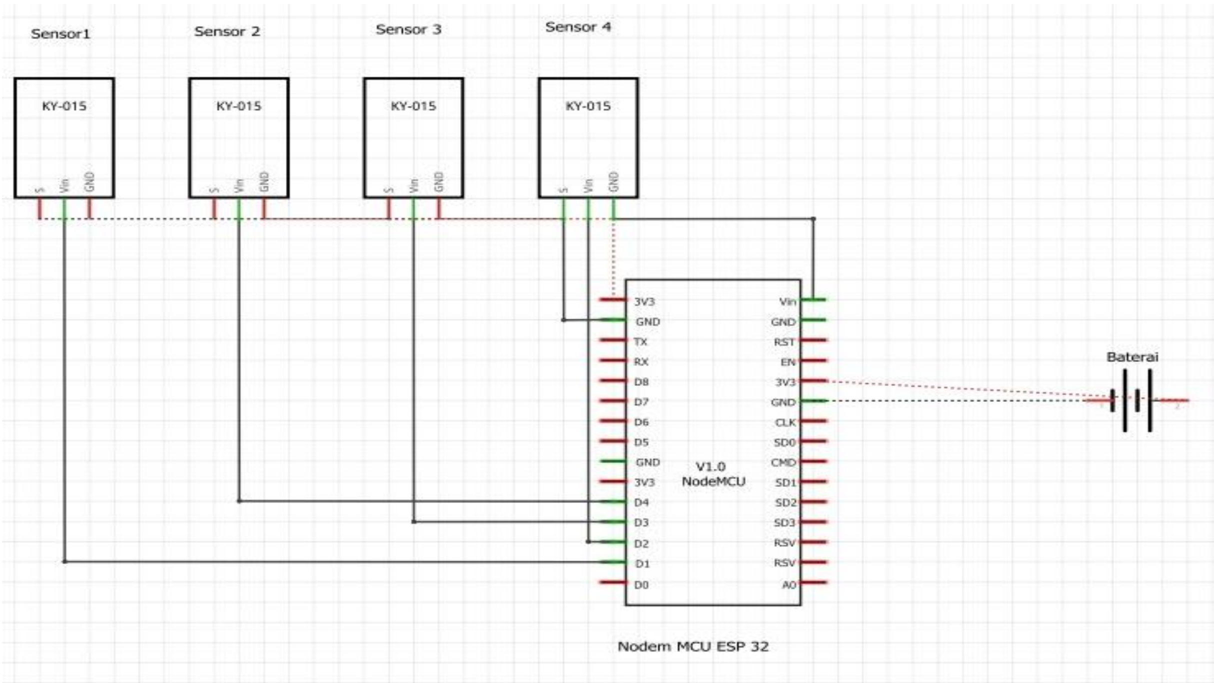

Figure 5. Preliminary Hardware Design

The KY-015 sensor comprises three main pins: S (Signal) for data output, Vcc for power input, and GND for ground connection. In this configuration, all sensors utilize a shared Vcc and GND line that runs parallel to the NodeMCU board. The signal pins of each sensor are connected to distinct GPIO pins on the NodeMCU ESP32: D1 (GPIO5), D2 (GPIO4), D3 (GPIO0), and D4 (GPIO2). This configuration enables the microcontroller to autonomously acquire temperature and humidity data from each sensor through its digital interface. The gathered data may serve for visualization, be stored in cloud systems, or be incorporated into an automated control framework.

Although the design is straightforward and effective, various technical considerations require attention. A concern arises from the fact that the NodeMCU outputs 3.3V, whereas KY-015 modules are typically designed for 5V operation. The voltage mismatch may adversely affect sensor performance. A proposed solution involves utilizing a step-up converter (3.3V to 5V) or a logic level shifter to guarantee voltage compatibility and maintain signal integrity. KY-015 sensors necessitate a pull-up resistor, typically between 4.7kΩ and 10kΩ, connected between the Vcc and signal pin to ensure stable communication. The absence of these resistors increases the likelihood of data transmission errors or missed readings.

The power supply system does not include a defined voltage regulator. Given that the system relies on a battery as its primary power source, it is essential to provide the NodeMCU with a stable 3.3V supply. A voltage regulator, such as the AMS1117-3.3V, is required if the battery provides voltage exceeding this level to avoid potential damage to the microcontroller. The components, including the NodeMCU board, sensors, and wiring, are physically protected by enclosing them in an acrylic casing. This enclosure features ventilation holes on the front or side panels to facilitate adequate airflow, enabling the DHT11 sensors to accurately measure environmental conditions. The acrylic box features cable access ports, allowing users to connect the NodeMCU to external power or reprogram it without the need to disassemble the entire enclosure.

RESULT AND DISCUSSION

Result

The data obtained from the DHT11 sensor indicate that its temperature measurement performance falls within the acceptable error tolerance standard when compared to a thermocouple reference. Over the course of three days of testing, all recorded error values remained within the technical tolerance limit of ±2°C. This suggests that the DHT11 sensor is effective for use in temperature monitoring systems with accuracy levels that are acceptable for general in-vehicle temperature surveillance during parking conditions. The measurements also revealed observable differences in temperature readings across the four sensors installed in various locations within the vehicle cabin. The results of the study are presented in Table 1 through Table 3.

Table 1. Temperature Test Results – Day 1 (DHT11 vs. Thermocouple)

No	Time	DHT11 Sensor (°C)	Thermocouple (°C)	Error Margin (°C)
1	08:58	36.3	36.9	0.01
2	09:59	48.2	39.3	-0.22
3	10:59	52.7	49.4	-0.06
4	11:59	60.1	58.5	-0.02
5	12:50	52.7	50.1	-0.05
6	13:50	52.9	49.6	-0.06
7	14:50	54.4	47.1	-0.15
8	15:51	53.9	46.6	-0.15

Table 1 displays the temperature measurements recorded from the DHT11 sensor and a thermocouple on the initial day of testing. The experiment was carried out at eight distinct time intervals, ranging from 08:58 AM to 03:51 PM, with both sensors functioning concurrently to evaluate their comparative accuracy. The error margin was determined by subtracting the thermocouple reading from the DHT11 reading at each time point. The data indicates that the DHT11 sensor typically measures higher temperatures than the thermocouple, especially in lower temperature ranges. At 09:59 AM, the DHT11 measured a temperature of 48.2°C, while the thermocouple recorded 39.3°C, leading to a notable error margin of -0.22°C. Conversely, smaller discrepancies were noted at other intervals, for instance, at 11:59 AM, where the DHT11 measured 60.1°C and the thermocouple recorded 58.5°C, resulting in a minimal error of -0.02°C.

The data indicates that the DHT11 sensor generally overestimates temperature readings in comparison to the thermocouple, particularly at lower temperature ranges. As ambient temperature increases, the discrepancies in measurements diminish, suggesting that the DHT11 exhibits enhanced accuracy at elevated temperatures. Various factors contribute to these variations, including sensor sensitivity, environmental conditions like humidity and air pressure, and the inherent technological limitations of the DHT11 sensor, which is typically less precise than thermocouples for high-accuracy applications [11].

Table 2. Temperature Test Results – Day 2 (DHT11 vs. Thermocouple)

No	Time	DHT11 Sensor (°C)	Thermocouple (°C)	Error Margin (°C)
1	09:27	31.8	32.1	0.009
2	10:58	44.8	39.5	-0.13
3	11:58	54.4	41.5	-0.31
4	12:58	59.0	46.4	-0.27
5	13:59	59.6	50.0	-0.19
6	14:59	58.5	42.0	-0.39
7	15:50	50.8	39.3	-0.29
8	16:20	47.7	35.4	-0.34

Table 2 summarizes the results of temperature measurements taken on the second day with DHT11 and thermocouple sensors. The table presents eight measurement time points, comparing the readings from both sensors and their respective error margins. Consistent with the prior day, the DHT11 sensor predominantly registered elevated temperature readings compared to the thermocouple during most of the measurement intervals. The minimum error margin recorded was 0.009°C at 09:27, whereas the maximum discrepancy was noted at 14:59, with an error of -0.39°C. The variations in error can be attributed to several factors, including differences in sensor sensitivity and accuracy, environmental conditions like humidity and air circulation, and the calibration quality of each sensor before testing. The temperature data indicate a consistent rise from morning to early afternoon, with maximum readings observed at 12:58 and 13:59. A downward trend in temperature was observed in the late afternoon, consistent with typical daily temperature cycles, which rise with solar radiation intensity and decline as sunlight diminishes [12]. The results from the second day of testing confirm that the DHT11 sensor consistently reports higher temperature values compared to the thermocouple. This distinction underscores the necessity of recognizing the limitations of the DHT11 in contexts demanding high precision.

Table 3. Temperature Test Results – Day 3 (DHT11 vs. Thermocouple)

No	Time	DHT11 Sensor (°C)	Thermocouple (°C)	Error Margin (°C)
1	08:38	30.2	30.3	0.003
2	09:36	49.2	39.6	-0.24
3	10:15	56.6	43.3	-0.30
4	11:19	52.2	48.9	-0.06
5	12:25	55.5	47.8	-0.16
6	13:21	58.4	55.6	-0.05
7	14:23	57.3	44.4	-0.29
8	15:32	52.7	40.5	-0.30

As shown in Table 3, the DHT11 sensor generally produced higher temperature readings than the thermocouple during the third day of testing. The recorded error margins ranged from as low as 0.003°C to as high as -0.30°C. In the first time point at 08:38, the difference between the two sensors was minimal (0.003°C), indicating a close agreement. However, as the day progressed, the discrepancies widened, with the largest deviations occurring at 10:15 and 15:32, both showing a -0.30°C margin. The temperature trend observed in this dataset indicates a gradual increase from morning until early afternoon, with the peak temperature recorded at 13:21—58.4°C for DHT11 and 55.6°C for the thermocouple. A decline followed in the late afternoon, mirroring the typical diurnal cycle of ambient temperature, where temperatures rise with solar radiation and fall as sunlight intensity decreases. These results confirm that the DHT11 sensor tends to report higher readings than the thermocouple, especially at elevated temperatures. While some time points showed only minor differences, others reflected more substantial discrepancies, suggesting that multiple environmental and technical factors influence each sensor's accuracy.

Through all three days of testing, the DHT11 sensor consistently recorded higher temperatures than the thermocouple. The largest error margin was observed on the second day at -0.39°C, while the smallest was 0.003°C on the third day. On the first day, the error range varied between 0.01°C and -0.22°C; on the second day, it ranged from 0.009°C to -0.39°C; and on the third day, from 0.003°C to -0.30°C. In general, the overall difference between the two sensors across all test sessions ranged from 0.003°C to 0.39°C, with larger deviations occurring at higher temperature readings. These findings indicate that although the DHT11 and thermocouple sensors display similar measurement trends, the DHT11's accuracy is comparatively limited, particularly in contexts requiring high precision. Therefore, when applied in temperature-sensitive environments, such as controlled laboratory settings or industrial monitoring, sensor selection should take into account the limitations observed in these comparative tests.

Discussion

The initial testing phase focused on validating the accuracy of the DHT11 sensor in measuring temperature and humidity. The sensor was placed in a controlled environment to ensure consistent ambient conditions, and its measurements were compared with a reference device. The results demonstrated that DHT11 displayed an average deviation of approximately ±1°C for temperature and ±2% RH for humidity, both of which fall within the sensor's specified tolerance range. The results confirm that DHT11 operates reliably under standard conditions and is suitable for fundamental environmental monitoring applications. Subsequent evaluations investigated the connectivity effectiveness of the NodeMCU microcontroller, namely its ability to transmit real-time data to Google Spreadsheet via Wi-Fi. The device connected to the wireless network within an average of 3–5 seconds after activation. Upon establishment of the connection, it consistently transmitted data at five-second intervals. Despite unsatisfactory network conditions—marked by delays of 10 to 15 seconds—the system maintained constant and accurate data logging without any loss. This demonstrates the robustness of NodeMCU's wireless data transfer capabilities, even in challenging conditions. Power efficiency was assessed utilizing a 2500mAh lithium battery as the principal power source, connected through a charging module and a 5V step-up converter to stabilize voltage for the NodeMCU. The system functioned uninterrupted for 6 to 8 hours prior to necessitating a recharge. The peak energy use occurred during Wi-Fi broadcasts. Thus, improving the transmission data interval may improve battery longevity, thereby augmenting the system's energy efficiency for portable applications [13].

The data sent to Google Spreadsheet was systematically arranged and readily analyzable, facilitating both tabular and graphical representations. This enabled users to monitor temperature and humidity patterns distinctly and precisely. Figure 6 demonstrates that the initial day of testing exhibited a significant temperature rise between 08:58 and noon, exceeding 60°C in several areas, while humidity levels concurrently diminished, reaching their nadir at approximately the same time. Temperature measurements from the four sensors (Temperature 1–4) exhibited uniform performance, however the four humidity sensors displayed an inverse trend, confirming sensor sensitivity to environmental changes.

Comparable trends were seen on the second and third days of testing, as illustrated in Figure 7 and Figure 8, respectively. On Day 2, the ambient temperature consistently increased before declining in the afternoon, while humidity levels drastically decreased throughout this ascent before rebounding in the evening. Day 3 demonstrated a consistent pattern, confirming the system's repeatability and reliability. The graphical outputs validate that the DHT11 sensors precisely record temporal temperature-humidity interactions within a car interior. Numerically, maximum temperatures varied from 55°C to 60°C, whereas minimum temperatures remained between 10°C and 15°C across the three-day period. Peak humidity levels ranged from 55% to 60% RH, while the minimum values decreased to between 5% and 15% RH. Although minor variations in the time of daily peaks and troughs were noted across the three datasets, the overall diurnal pattern remains unchanged. These variations likely indicate extrinsic influences such as solar exposure, airflow dynamics, and vehicle placement.

The real-time graphical data presented by the system (Figures 6–8) validate its capacity to identify and visualize environmental changes proficiently. The integration of DHT11 sensors, NodeMCU, and Google Sheets resulted in a useful, responsive, and portable monitoring device. The system's reliable performance over several days validates its suitability for temperature and humidity monitoring in enclosed spaces such as car cabins.

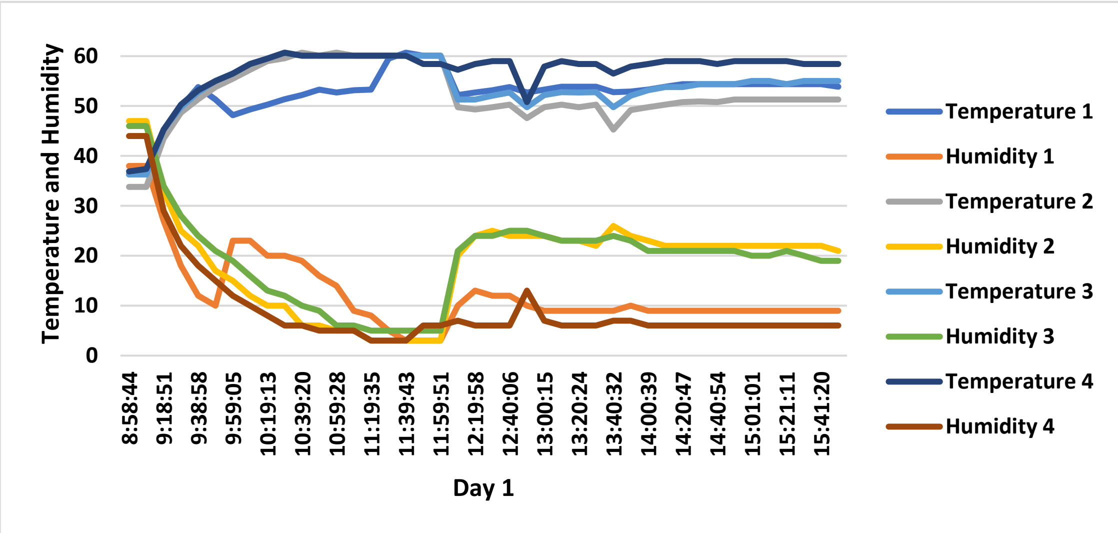

Figure 6. First Day Testing Results of Temperature and Humidity

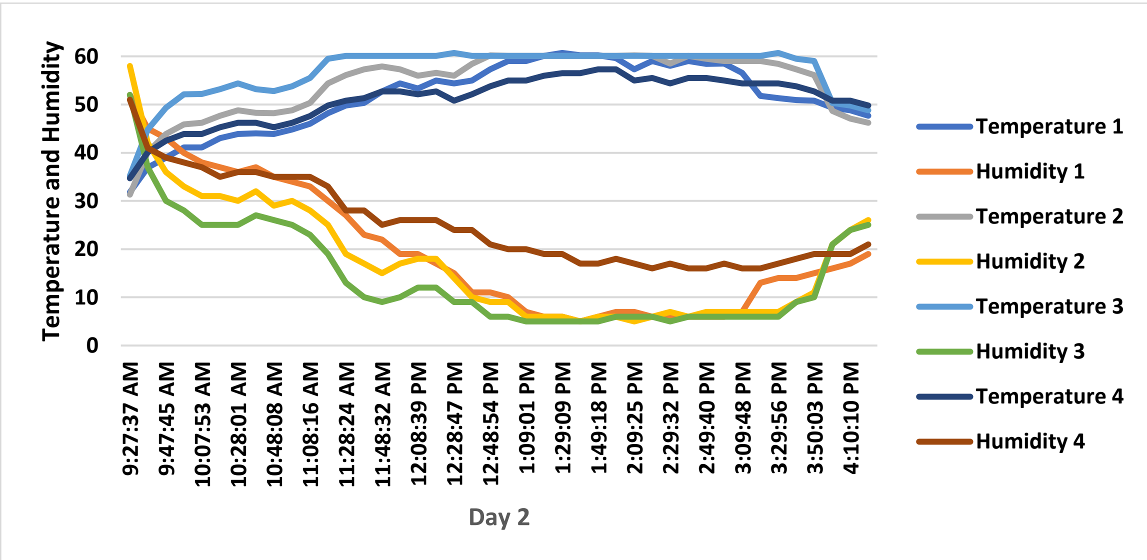

Figure 7. First Two Testing Results of Temperature and Humidity

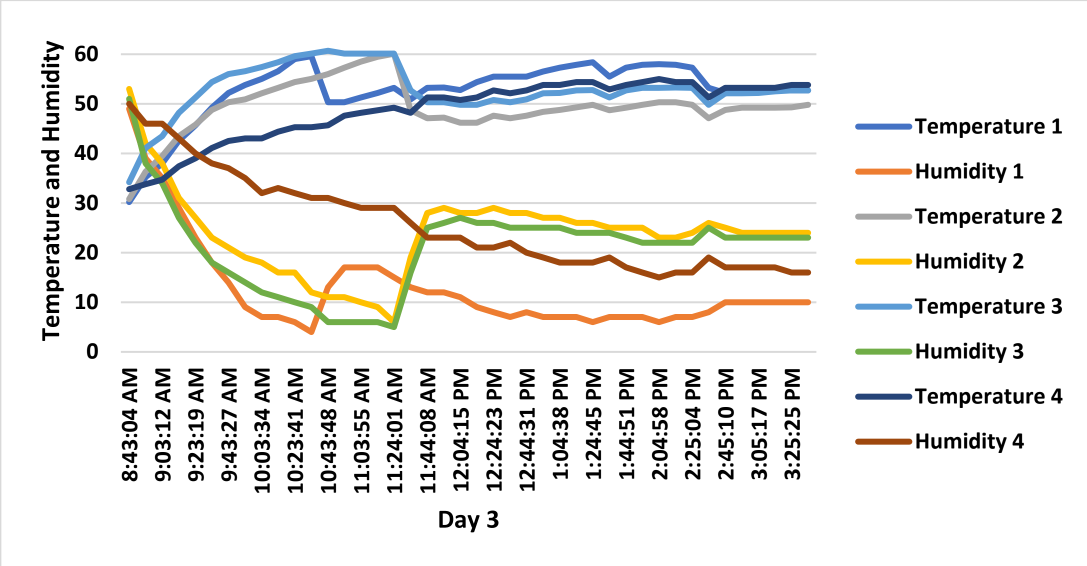

Figure 8. First Three Testing Results of Temperature and Humidity

CONCLUSION AND RECOMENDATION

Conclusion

This study aimed to evaluate the efficacy of an IoT-based system in recording, monitoring, and analysing temperature and humidity fluctuations within a vehicle cabin utilizing the DHT11 sensor and NodeMCU microcontroller. The testing and analysis indicate that this system effectively aids users in real-time environmental monitoring and control, especially in scenarios involving parked vehicles where temperature variations may be considerable. The system exhibited reliable performance in capturing temperature and humidity data via four DHT11 sensors strategically placed within the cabin. The data was successfully transmitted and stored in real-time on Google Spreadsheet, with measurements recorded at intervals from 08:58:44 AM to 03:41:20 PM. The temperature and humidity measurements were classified into four categories—Temperature 1 to Temperature 4 and Humidity 1 to Humidity 4—each linked to distinct sensor locations within the cabin, offering a thorough temporal and spatial representation of cabin conditions. The graphical study indicated a constant trend of rising temperatures leading to midday, presumably influenced by solar radiation, followed by a gradual decrease in the afternoon. Humidity had an inverse correlation, decreasing with rising temperatures and increasing during cooler intervals. Minor variations in these parameters may be ascribed to external influences such as air circulation or ancillary heat sources. The DHT11 sensor, connected with NodeMCU and facilitated by cloud-based data logging through Google Spreadsheet, demonstrated an effective and pragmatic method for monitoring cabin temperature and humidity. The system effectively recorded environmental changes with adequate precision and responsiveness, rendering it a suitable instrument for automobile or other confined-space environmental control applications.

Recommendation

To enhance the functionality of the DHT11-based temperature monitoring system, it is recommended that future developments incorporate an automated notification feature that alerts users when temperature readings exceed predefined thresholds. Such alerts can be delivered through SMS, email, or Android-based applications, enabling real-time responses to abnormal temperature conditions and helping to maintain environmental stability in the monitored area. From a technical perspective, further improvements may include integrating automated data logging to cloud storage services, which would allow for more secure and scalable data management. Additionally, the system could be expanded by incorporating supplementary sensors—such as gas or advanced humidity modules—to broaden the scope of environmental monitoring. To improve usability and accessibility, a web-based or mobile application interface could also be developed. This would allow users to visualize and interact with temperature trends and historical data more intuitively. These enhancements would increase the system's reliability and flexibility, making it better suited for various controlled environments such as laboratories, greenhouses, or storage facilities.

REFERENCES

[1] F. Purwanto, "Perancangan dan Implementasi Sistem Monitoring Gas Berbahaya Pada Mobil Berbasis Logika Fuzzy Menggunakan Mikrokontroler," *e-proceeding of engginering*, vol. 3, no. 3, hal. 4657, 2016.
[2] B. Suhendar, T. D. Fuady, dan Y. Herdian, "Rancang Bangun Sistem Monitoring dan Controlling Suhu Ideal Tanaman Stroberi Berbasis Internet of Things (IoT)," *J. Ilm. Sains dan Teknol.*, vol. 5, no. 1, hal. 48–60, 2020, doi: 10.47080/saintek.v5i1.1198.
[3] W. Wajiran, S. D. Riskiono, P. Prasetyawan, dan M. Iqbal, "Desain Iot Untuk Smart Kumbung Dengan Thinkspeak Dan Nodemcu," *POSITIF J. Sist. dan Teknol. Inf.*, vol. 6, no. 2, hal. 97, 2020, doi: 10.31961/positif.v6i2.949.
[4] M. Setiyo, B. Waluyo, N. Widodo, M. L. Rochman, S. Munahar, dan S. D. Fatmaryanti, "Penilaian Efek Pendinginan dan Indeks Panas (HI) Pada Pendingin Kabin Mobil Bertenaga Panel Surya Di Mobil Yang Di Parkir," *Case Stud. Therm. Eng.*, vol. 28, no. August, hal. 101386, 2021, doi: 10.1016/j.csite.2021.101386.
[5] A. R. Halim, M. Saiful, dan L. Kertawijaya, "Rancang Bangun Alat Pengukur Suhu Tubuh Pintarberbasis Internet Of Things," *Infotek J. Inform. dan Teknol.*, vol. 5, no. 1, hal. 117–127, 2022, doi: 10.29408/jit.v5i1.4615.
[6] R. Wulandari, "Rancang Bangun Pengukur Suhu Tubuh Berbasis Arduino Sebagai Alat Deteksi Awal Covid-19," *Pros. SNFA (Seminar Nas. Fis. dan Apl.*, vol. 5, hal. 183–189, 2020, doi: 10.20961/prosidingsnfa.v5i0.46610.
[7] H. Isyanto, W. Ibrahim, dan P. Mashuri, "Rancang Bangun Smart AC Portable Berbasis Internet of Things (IoT)," *Resist. (Elektronika Kendali Telekomun. Tenaga List. Komputer)*, vol. 4, no. 2, hal. 137, 2021, doi: 10.24853/resistor.4.2.137-146.
[8] A. Jupri, A. Muid, dan - Muliadi, "Rancang Bangun Alat Ukur Suhu, Kelembaban, dan pH pada Tanah Berbasis Mikrokontroler ATMega328P," *J. Edukasi dan Penelit. Inform.*, vol. 3, no. 2, hal. 76–81, 2017, doi: 10.26418/jp.v3i2.21210.
[9] Sugiyono, *Metode Penelitian Kuantitatif, Kualitatif, R&D*. Bandung: IKAPI, 2016.
[10] Sugiyono, *Metode Penelitian Kuantitatif, Kualitatif, dan R&D*. Bandung: Alfabeta, 2012.
[11] R. Y. Bait, I. Fahmi, dan L. F. Boesday, "Desain Alat Dispenser Hand Sanitizer Otomatis Menggunakan Sensor Ultrasonic Berbasis Arduino Nano," *J. Spektro*, vol. 6, no. 1, hal. 31–38, 2023.
[12] D. Sasmoko dan A. Mahendra, "RANCANG BANGUN SISTEM PENDETEKSI KEBAKARAN BERBASIS IoT dan SMS GATEWAY MENGGUNAKAN ARDUINO," *Simetris J. Tek. Mesin, Elektro dan Ilmu Komput.*, vol. 8, no. 2, hal. 469, 2017, doi: 10.24176/simet.v8i2.1316.
[13] F. Azharul, Rahmawati, Choiruddin, dan Wilarso, "Rancang Bangun Alat Kalibrasi Pengukur Suhu Berbasis Digital Temperatur Controller," *TEKNOSAINS J. Sains, Teknol. dan Inform.*, vol. 8, no. 2, hal. 109–116, 2021, doi: 10.37373/tekno.v8i2.103.