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IoT-Enabled Laundry Drying Rack for Smart Home

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ABSTRACT

This study proposes the design and implementation of an IoT-enabled laundry drying rack specifically for smart home applications. It is particularly suitable for residents of tropical regions, where drying clothes mostly depends on sunlight, thus eliminating energy consumption in the drying process. The device consists of a drying rack and clothes hangers. The drying rack features a set of sliding rails and a carriage mechanism that allows clothes to be extended for drying and retracted when they are dry or in the event of rain. The system operates in two modes: auto and manual. In auto mode, the rack automatically retracts the carriage to store the clothes once they are dry, when rain is detected, or when the system detects heavy cloud cover indicating potential rainfall. In manual mode, users are able to control the movement of the carriage as desired. Additionally, the system enables users to monitor the status of drying clothes and weather conditions through a mobile application. An evaluation of the system's performance in measuring humidity showed that the sensor readings correlated strongly with data from weather services like Weather.com and AccuWeather.com, with discrepancies not exceeding 7%. In terms of operational accuracy, the system demonstrated a performance efficiency rate of 97.87%.

Keywords: Internet of Things, laundry drying rack, smart clothes drying rack, smart home.

INTRODUCTION

Clothing is one of the fundamental necessities of life, and its styles and materials vary based on geography and climate. In colder regions, people typically wear garments made from materials such as fur, wool, cashmere, and leather, often layering them for added warmth. In contrast, individuals in tropical climates prefer light, breathable fabrics like cotton and linen, prioritizing comfort and ventilation. As a result, climate significantly influences how people care for and maintain their clothing, particularly in drying methods. In colder countries, clothes are often dried indoors using electric dryers or hung near heat sources. In tropical regions, garments are more commonly air-dried outdoors, taking advantage of warm, dry weather. However, drying clothes in tropical countries can present challenges, including high humidity, frequent rainfall, intense sunlight, and limited drying space. To address these issues, we developed a smart Internet of Things (IoT) clothing-drying rack. This device includes humidity and rain sensors to assess the moisture level of the fabric, automatically activating a motor to retract the rack indoors when necessary.

The Internet of Things (IoT) connects multiple devices and objects, promoting efficient collaboration within a network [1]. Its applications span a wide range of sectors, including industry, education, healthcare, agriculture, manufacturing, and domestic use [2] [3] [4].

LITERATURE REVIEW

Laundry Drying

Laundry drying practices vary significantly around the world, influenced by climate, culture, infrastructure, and technology. Generally, drying methods can be divided into two main categories: air drying and machine drying. Air

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drying involves hanging clothes outside on a clothesline or drying rack, allowing them to dry through natural processes, primarily sunlight, wind, and ambient air circulation as depicted in Figure 1. This method is widely used in many regions, particularly those with ample sunlight and favorable weather conditions [5].

Figure 1. Laundry drying

On the other hand, machine drying with electric dryers is commonly found in colder climates or areas where rapid drying is necessary. In countries such as the United States, Canada, and northern European nations, electric tumble dryers are standard in many homes, especially during winter months when outdoor drying is not practical due to low temperatures and high humidity. In tropical regions, characterized by high temperatures and humidity, air drying is the predominant method. Although humidity presents challenges, sunlight and wind are usually adequate for drying clothes. Clotheslines and drying racks are typically used outdoors, taking advantage of direct sunlight and breezes to speed up the drying process.

Lin et al. [6] proposed the development of an intelligent drying rack that builds upon traditional laundry drying racks by integrating sensors to detect sunlight and rain. A light sensor is used to monitor light levels and identify the transition between day and night. This intelligent drying rack can automatically move laundry from indoors to outdoors on sunny days and from outdoors back indoors during the night or in the event of rain.

Tan et al. [7] developed an automatic clothes-drying rack utilizing Internet of Things (IoT) technology, which includes both hardware and software components. The hardware features an STM32 chip and sensors that detect and prevent clothes from getting wet due to rain. Additionally, ultraviolet (UV) LED lights and PTC warm air fans are incorporated to provide synchronized drying and sterilization functions, ensuring that clothes dry thoroughly without developing dampness or mustiness. The system also allows for communication between the device and the user via a mobile application, enabling users to monitor the status of their laundry at any time.

Muhammad et al. [8] introduced a smart, solar-powered outdoor laundry drying system that employs the OMRON PLC system as its central controller for a motorized, stretch-and-retract mechanism. This prototype utilizes solar energy to operate the automated clothesline, contributing to reduced energy consumption and carbon emissions. The system offers both manual and automatic modes, allowing users to control the movements of the DC motor that extends or retracts the scissor-like cloth hanger. Furthermore, researchers have proposed an Intelligent Clothes Drying System that incorporates Real-Time Monitoring and Control features [9]. This system leverages artificial intelligence to assess the condition and drying time of fabrics. Its primary components include moisture sensors, load cell weight sensors, a microcontroller for the dryer, a hot air blower, and an LED display to show both time and temperature.

Currently, there is a variety of smart drying racks available on the market. For instance, the SDR702 [10] is a smart clothes drying-rack with a load capacity of 35 kg, allowing it to accommodate a larger quantity of clothes for drying at once. If the load exceeds 35 kg, the motor automatically stops, and the rack issues an alert to ensure user safety. The device also features two fans to facilitate moisture removal and a heater that generates temperatures ranging from 40 to 45°C to assist in drying clothes on rainy days.

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Temperature and Humidity Sensors

The DHT22, as illustrated in Figure 2, is a cost-effective temperature and humidity sensor that is readily available on the market. It communicates with microcontroller units (MCUs) through a single digital signal line, using a one-wire bus for bi-directional serial data exchange. The operating voltage for this sensor ranges from 3.3 V to 5.5 V DC. Its internal structure includes a polymer capacitor as the sensing element, allowing temperature measurements between -40 and 80 °C with an accuracy of ±0.5 °C. Additionally, it measures relative humidity from 0 to 100% RH with an accuracy of 2 to 5%. The DHT22 can achieve a maximum measurement frequency of 0.5 Hz and features a 4-pin connector with a spacing of 0.1 inches (2.54 mm) [11]. A pull-up resistor circuit is necessary for stable operation.

Figure 2. DHT22 - Temperature-humidity sensor

Light Intensity Sensor

The BH1750, shown in Figure 3 (right), is designed to measure light intensity in lumens per square meter (lux). It has a broad measurement range and high resolution (1-65535 lux). This sensor is capable of detecting visible light in a manner that closely resembles human vision, with optimal responsiveness to wavelengths between approximately 500 and 600 nanometers [11]. The sensor incorporates noise filtering at frequencies of 50 Hz and 60 Hz to minimize detection errors. Communication is achieved through an Inter-Integrated Circuit (I2C) interface, providing a 16-bit digital output of light measurements. It operates on a supply voltage range of +3.3V to +5V and is characterized by low power consumption due to its energy-saving mode.

Rain Sensor

The rain sensor, illustrated in Figure 3 (left), measures rainfall using two components: a sensor plate and a voltage comparator module. The sensor plate has parallel conductive traces. When rain falls, the resistance between these traces decreases since rainwater conducts electricity. The voltage comparator module reads this change in resistance and provides both analog and digital output signals. The sensor's sensitivity is adjustable, and it operates on a 3.3 V to 5 V DC power supply [11].

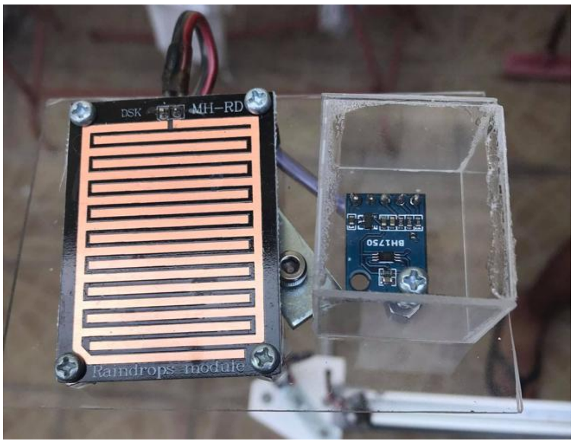

Figure 3. Rain sensor (left) and Light intensity sensor (right)

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REQUIREMENT GATHERING AND ANALYSIS

This research focuses on designing and developing a clothes-drying rack specifically for residents of tropical regions. The rack utilizes natural sunlight and wind for outdoor drying, thereby eliminating the need for electrical power. However, this natural drying process can be time-consuming, and users may not always be home during this period. Additionally, the tropical climate poses challenges due to occasional rain. Based on surveys and collected requirements from stakeholders, the key needs summarized using the requirements engineering framework [12] are as follows:

1) Solar and Wind Drying: The drying rack should enable outdoor drying using wind and sunlight, avoiding energy consumption for cost savings and environmental benefits.
2) Automated Retraction: The rack must feature an automatic retraction system to pull clothes hangers inside when they are dry or in anticipation of sudden rainfall.
3) Remote Environmental Monitoring: Users should be able to monitor environmental conditions, such as light levels and impending rain, remotely via their smartphones.
4) Remote Clothes Monitoring: Users should be able to check the drying status of their clothes (wet, damp, nearly dry, or dry) remotely via their smartphones.
5) Remote Control: The system should allow users to remotely retract the clothes rack from their mobile phones when they are away from home.
6) User-friendly Interface: The system should be easy to use and understand for local residents, incorporating a user-friendly interface and accessible language.

SYSTEM ARCHITECTURE

This section describes the system architecture, which consists of three main components: a server, an IoT sensor module, and an IoT actuator module, as illustrated in Figure 4.

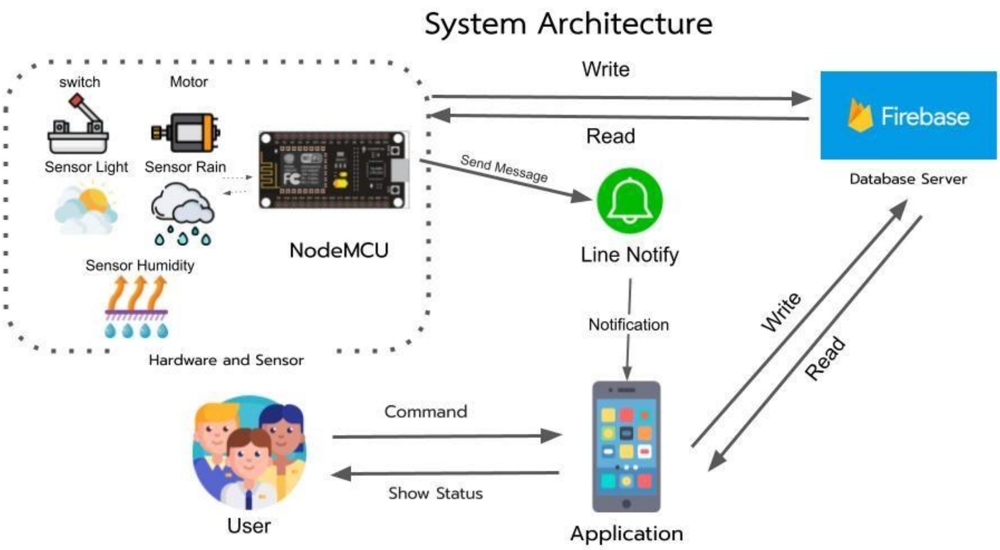

Figure 4. System architecture

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Sensor Module

The sensor module comprises a NodeMCU ESP8266 Wi-Fi-enabled microcontroller, along with three distinct sensors. Firstly, a BH1750 light intensity sensor measures ambient light levels to assess sky conditions, determining whether it is cloudy, overcast, or raining. If significant cloud cover is detected, which could indicate potential rainfall, the system automatically retracts the clothes rack to a sheltered position. Secondly, three DHT22 humidity sensors are employed: one monitors the ambient humidity, while the remaining two measure humidity at the clothespins. Data from all three sensors are processed to determine whether the laundry is dry. Finally, a rain sensor detects the presence of precipitation.

Actuator

The actuator is responsible for controlling the movement of the carriage slider, which is used for extending and retracting the clothesline. It is driven by a high-torque geared motor and a belt system. The carriage automatically retracts the laundry under specific conditions: when the clothes are dry or when darkening skies, heavy cloud cover, or the onset of rain are detected. Limit switches are installed at both ends of the track to monitor and restrict the carriage's movement, ensuring it remains within its operational range, whether fully extended or fully retracted (to store the dry laundry).

Services

Two primary services are utilized in this system: Firebase and the LINE Messaging API. Firebase acts as an intermediary server that facilitates communication between the clothes hanger and the clothes rack. It collects data from various environmental sensors, including humidity levels, the moisture content at the clothespins, and atmospheric conditions. Additionally, it compiles information regarding temperature, environmental humidity, and the drying time of the clothes, enabling the system to provide timely recommendations on the optimal drying duration. The LINE Messaging API serves as the notification mechanism through the LINE application, alerting users about weather conditions, rain forecasts, and the status of the clothes drying process via a mobile interface.

IMPLEMENTATION

This section describes the implementation of both hardware and software.

Drying Rack

The drying rack, as depicted in Figure 5, is designed for hanging freshly washed clothes. It consists of a frame and a sliding rail system. The rack includes a carriage mechanism that allows clothes hangers to move, enabling the rack to either extend or retract for storing dried clothes. The sliding motion is powered by a high-torque motor and a belt drive system. The carriage automatically retracts the clothes when they are dry or when rain is detected. Limit switches are installed at both ends of the rail to detect and restrict the carriage's position, ensuring it stops at either the fully extended or fully retracted positions (for storing clothes).

The system also features a rain detection mechanism that includes a light sensor and a rain sensor. The light sensor monitors weather conditions to detect if the sky is cloudy, overcast, or if rain is imminent. If the weather becomes cloudy, rain begins to fall, or heavy rain occurs suddenly, the carriage will automatically retract to store the clothes. The circuit diagram is illustrated in Figure 10.

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Figure 5. Drying rack

Clothes Hanger

The clothes hanger, as illustrated in Figure 6, is a standard garment hanger equipped with a humidity sensor located at a single point on the hanger. Additionally, two humidity sensors are attached to the clothespins, as shown in Figure 7. This system is designed to attach the clothespins containing humidity sensors to the thickest part of the hung fabric, as demonstrated in Figure 8. The sensors measure humidity levels at all three points: two on the clothespins, and one for the surrounding environment. The detected humidity levels are then compared to the ambient humidity. When the desired dryness level is reached, the drying rack automatically retracts the clothes rack.

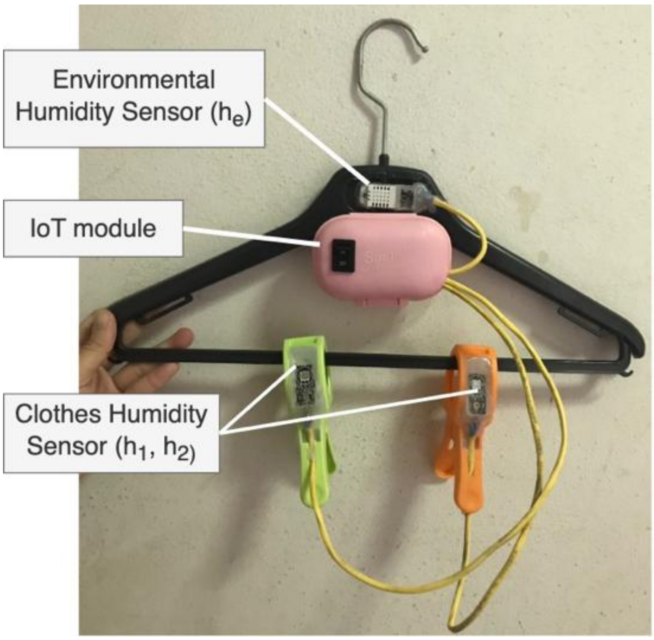

Figure 6. Clothes hanger

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Figure 7. Humidity sensor attached at the clothespins

Figure 8. Clothes hanging

Client

The mobile application interface consists of two main sections: the dashboard and the settings, as illustrated in Figure 9. The dashboard displays real-time information about the moisture level of hanging laundry, current weather conditions, and the operational status of the drying rack. Moisture levels are represented visually using a six-tier icon system that categorizes the laundry into six states: soaking wet, wet, damp, moist, nearly dry, and dry. The settings section allows users to adjust the operational mode of the drying rack, which can be set to either automatic or manual. In automatic mode, the carriage will return to its storage position on its own, whereas in manual mode, users can control the carriage to extend or retract using the mobile application.

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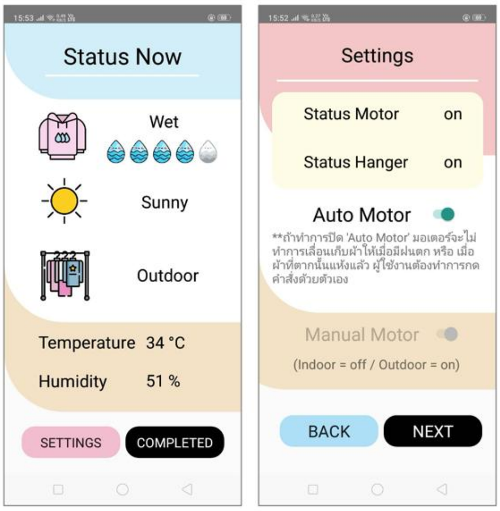

Figure 9. Mobile application

Laundry Dryness Index

The laundry dryness index is calculated using a relative humidity measurement. This process involves three humidity sensors: one sensor measures the ambient humidity, while two additional sensors are attached to clothespins that are secured to the thickest parts of the clothes. The humidity readings from the clothespins are then compared to the ambient humidity to determine the relative humidity index, as outlined below and in Table 1.

$$h_d = \max(h_1, h_2) - h_e$$

h_d represents the dryness index of the laundry. h_1 and h_2 denote the humidity levels measured by two humidity sensors installed on the clothespin, which assess the humidity content at two distinct points on the laundry. Meanwhile, h_e indicates the humidity level of the surrounding environment.

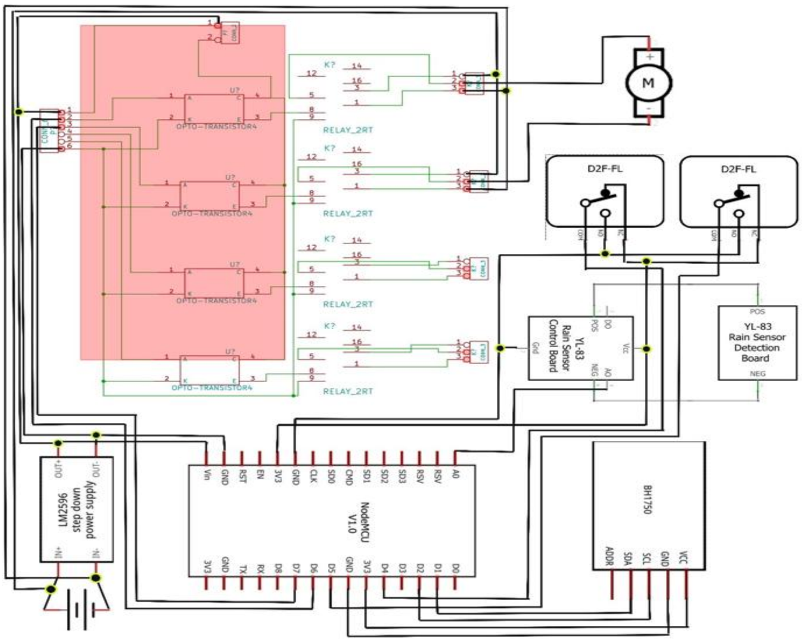

Figure 10. Schematic diagram

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Table 1. Laundry dryness.

Dryness index (h_d)	Laundry State	Indicators on Mobile Application
>= 30	Soaking Wet	
25 - 29.9	Wet	
20 – 24.9	Damp	
15 – 19.9	Moist	
10.1 – 14.9	Nearly dry	
<= 10	Dry	

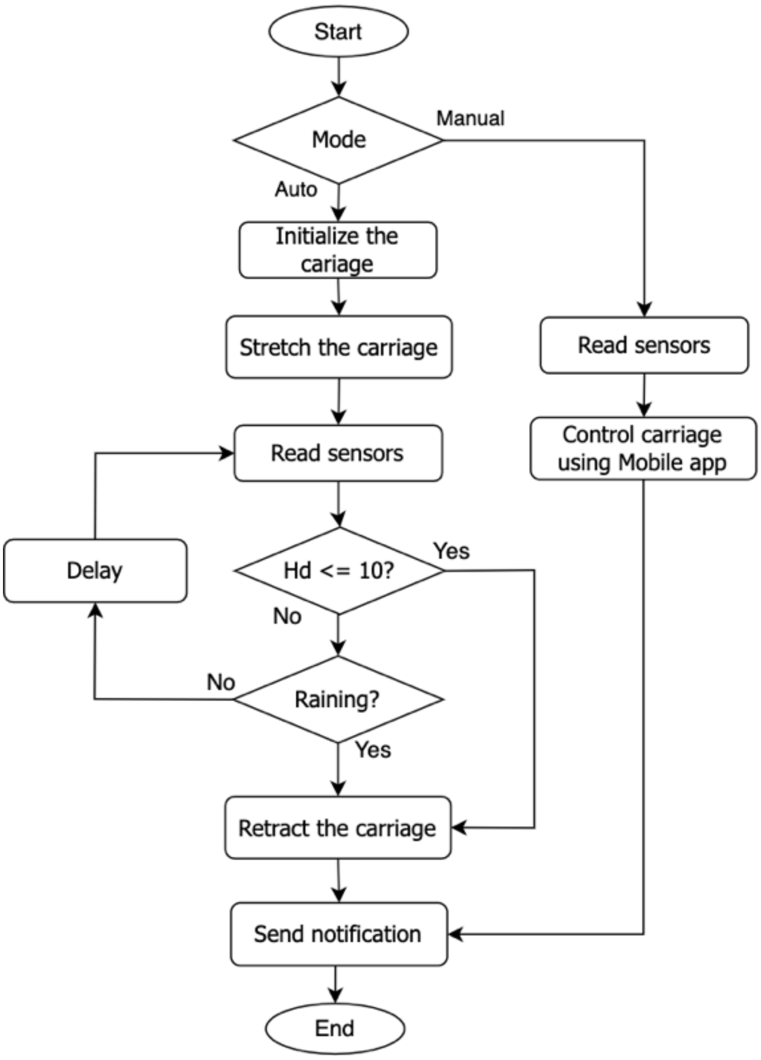

Figure 11. System flow

The system's workflow, as illustrated in Figure 11, begins with the user selecting their preferred operational mode. In automatic mode, the carriage is initialized to identify the positions at both ends of the sliding rail. Once this is complete, the carriage extends to prepare for hanging the laundry. The system then reads the sensors; if the humidity index (h_d) is 10 or lower, it indicates that the laundry is dry. In this case, the carriage retracts, and the user

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receives a notification that the laundry is ready for collection. However, if the humidity index is greater than 10 or if there is no rain, the system will wait a few seconds before re-reading the sensors in the next iteration.

RESULTS

The evaluation focused on two key aspects: humidity measurement results and overall system performance. For the humidity measurement results, we compared the ambient humidity levels obtained from our sensor with those reported by two weather services: AccuWeather and The Weather Channel. Our findings showed that the sensor's humidity readings aligned consistently with the values provided by these services, as illustrated in Figure 12. We analyzed the discrepancies between the measurements and found that the differences did not exceed 7%. Therefore, we conclude that the humidity readings from the clothes drying sensor are reliable for practical use.

Regarding system performance, the sensor achieved an accuracy rate of 97.87%. The few inaccuracies observed were mainly attributed to persistent heavy rain during the night, which resulted in increased humidity levels.

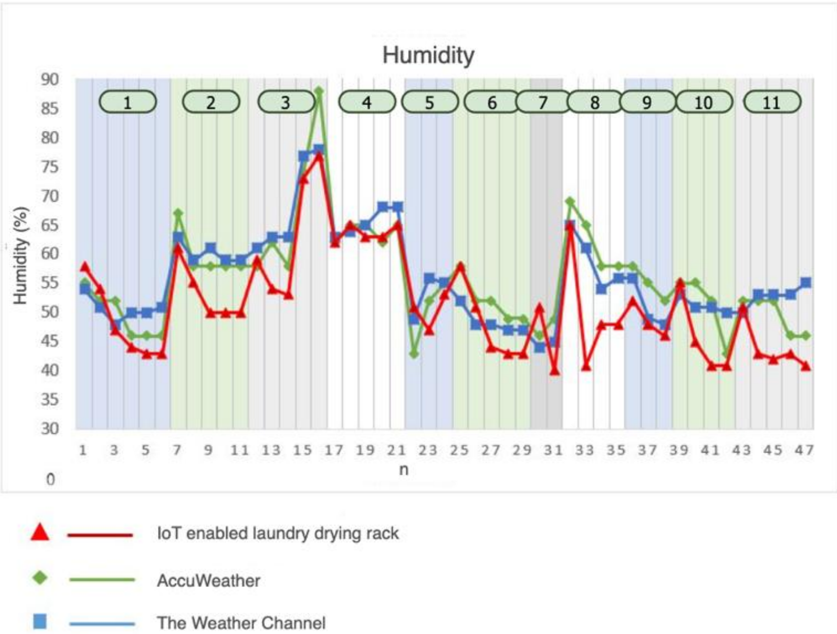

Figure 12. Humidity comparison chart

CONCLUSION

In this study, we designed and developed an Internet of Things (IoT) enabled laundry drying rack utilizing IoT technology. This system is particularly well-suited for populations living in hot and humid climates where sunlight is primarily used for drying clothes. The system consists of a drying rack and a clothes hanger.

The drying rack features a sliding rail and carriage mechanism, allowing for efficient extension and retraction of the rack for either hanging or storing clothes when they are dry or in the event of rain. The clothes hanger utilizes standard hangers equipped with humidity sensors: one at a specific location on the hanger and two located on the clothespins. The operational process involves attaching the clothespin to the thickest part of the clothing. The system compares the humidity readings from the sensors with the ambient humidity to determine if the drying rack should retract and store the clothes. Users can choose between two control modes:

1) Automatic Mode: The rack automatically retracts to store clothes once they are dry, or if rain is detected, or in overcast conditions that suggest a likelihood of rain.
2) Manual Mode: Users can manually command the carriage to retract according to their preferences.

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Additionally, users can monitor the status of the drying clothes and weather conditions through a mobile application.

The evaluation results were categorized into two main aspects: humidity measurement and operational efficiency. The humidity values obtained from the sensors showed a strong correlation with readings from Weather.com and Accuweather.com, with a variance of no more than 7%. Therefore, the humidity measurements from the drying rack are considered reliable for practical use. The system demonstrated an accuracy rate of 97.87% in terms of accuracy and operational effectiveness.

REFERENCES

[1]. K. Saraubon and B. Limthanmaphon, "*Cordyceps IoT-based Smart Farm Control System*," Journal of Electrical Systems, vol. 20, no. 9s, pp. 1652-1661, 2024.
[2]. K. Saraubon and B. Limthanmaphon, "*IoT Telemonitoring System for COVID-19 Quarantine*," TEM Journal, vol. 10, no. 1, pp. 105-112, 2021.
[3]. K. Saraubon, N. Wiriyanuruknakon and N. Tangthirasunun, "*Flashover Prevention System Using IoT and Machine Learning for Transmission and Distribution Lines*," International Journal of Interactive Mobile Technologies, vol. 15, no. 11, pp. 34-48, 2021.
[4]. S.A.Sundi, M. Jumali, M. Yunos and M. Ahmad, "*Design & Development of Smart Clothes*," International Journal of Recent Technology and Engineering (IJRTE), vol. 8, no. 1S5, pp. 108-113, 2019.
[5]. O. W. Lynn, "*Hang-and-Go: A Smart Laundry Hanging System*," Universiti Teknologi PETRONAS, 2015.
[6]. Y.-H. Lin, Y.-C. Lee and C.-P. Chang, "*Establishing an Intelligent Laundry Drying Rack Using System Innovation Theory*," in International Conference on Energy and Power Engineering, 2020.
[7]. X. Tan, L. Yang, Y. He and J. Chen, "*Research on IoT-based Smart Clothes Drying Rack*," in International Conference on Internet of Things, Automation and Artificial Intelligence, Nanchang, China, 2023.
[8]. K. A. I. M. F. B. Muhamad Zulhairie Azmi1, Z. Z. Abidin and M. Jenal, "*Enhancement of Accessibility and Sustainability: A Smart Solar-Powered Outdoor Laundry Drying System*," Majlesi Journal of Electrical Engineering, vol. 17, no. 4, pp. 63-72, 2023.
[9]. G. Kurkure and S. Ramani, "*Development Of an Intelligent Clothes Drying System with Real-Time Monitoring and Control*," The Internet of Things and Artificial Intelligence Journal, vol. 3, no. 2, pp. 121-128, 2023.
[10]. Philips, "*Smart clothes drying rack*," 2023. [Online]. Available: https://www.documents.philips.com/. [Accessed December 2024].
[11]. A. Industries, "*Products,*" [Online]. Available: https://www.adafruit.com/. [Accessed December 2024].
[12]. R. S. Pressman and B. Maxim, *Software Engineering: A Practitioner's Approach* 8th Edition, 8 ed., New York: McGraw-Hill, 2015.