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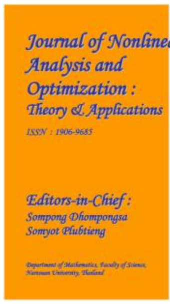

DEVELOPMENT OF AN IOT-ENABLED MICROCONTROLLER SYSTEM FOR MEASURING RAINFALL INTENSITY

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Abstract

The design of an IoT-based rainfall intensity measuring device using a microcontroller offers a more accurate, efficient, and real-time alternative to traditional manual systems. While manual methods are still prevalent, they suffer from notable drawbacks, such as dependency on human observation, slow response times, and inaccurate measurements. This study presents a system utilizing a tipping bucket rain sensor connected to an ESP32 or ESP8266 microcontroller, along with a Wi-Fi module for real-time data transmission to a cloud-based IoT platform. The system processes the collected data and presents it through graphical visualizations, accessible via web or mobile applications. This enables continuous rainfall monitoring and ensures fast, precise data delivery, which can be crucial for disaster mitigation, agricultural planning, and natural resource management. By integrating IoT technology, this design overcomes the limitations of manual systems, providing real-time, reliable rainfall data. The system's ability to monitor rainfall intensity and transmit data instantaneously facilitates timely, data-driven decisions that benefit various fields, such as environmental management and emergency response. Furthermore, the ease of accessing visualized data via online platforms enhances its usability for different users, making it a valuable tool for researchers, policymakers, and practitioners involved in weather-dependent activities. Overall, this IoT-based system presents a significant advancement in rainfall measurement, offering improved accuracy and operational efficiency compared to traditional manual methods.

Keywords:

IoT-based, Rainfall intensity, Microcontroller, Tipping bucket sensor, Real-time data transmission

1. GENERAL INTRODUCTION

Rainfall significantly impacts sectors such as agriculture, water management, urban planning, and disaster prevention. Accurate rainfall intensity measurement is essential for weather pattern analysis, flood prediction, and resource management [2]. However, traditional instruments often fall short due to limitations in device availability, outdated technology, and the lack of real-time data, affecting forecasting and disaster response accuracy [4]. IoT technology, which enables real-time data transmission and remote monitoring, offers a solution to these issues. By integrating IoT with microcontrollers, rainfall data can be collected and transmitted to cloud platforms, ensuring continuous monitoring and faster decision-making for applications like flood forecasting and water management [5]. This reduces reliance on manual systems, increasing efficiency and accuracy [6]. Using microcontrollers, rainfall data is automatically processed and transmitted for storage and analysis, facilitating quick dissemination for flood warnings and irrigation planning [7]. This study focuses on developing an IoT-based rainfall intensity measuring tool using a microcontroller, offering an efficient, cost-effective, and real-time solution for communities and agencies dependent on accurate rainfall data [8]. Methods such as Pluviometers, Automatic Weather Stations, and satellite data are commonly used for rainfall measurement, with each offering specific advantages in different regions [9][10]. The Arduino microcontroller, with its open-source nature, supports the development of rainfall measurement tools that display real-time data and store it for further analysis [13].

2. RESEARCH METHODOLOGY

This study employs several methods to gather data and develop the monitoring system.

1. Field Research

The first method is field research, which involves conducting observations in the field and performing simulations on the created system.

This research is carried out in two ways:

a) Interview: Interviews, where data is collected through direct questioning and answering with authorized individuals within the school, providing a comprehensive view of the existing information system.

Interviews require a strong and democratic relationship between the interviewer and the interviewee, and they serve two purposes:

1) Collecting primary data directly from respondents and
2) Obtaining information when other methods are not feasible.

b) Observation

Which involves studying all relevant documents and records to collect necessary data?

2. **Library Research:** The second method is library research, where data is collected by reading and studying books and reference materials pertinent to the research topic.

3. Laboratory Research: The third method is laboratory research, where the researcher processes the information gathered and designs the desired application based on existing data.

System analysis is crucial as it involves identifying and understanding the research problems to determine suitable solutions. It allows for the assessment, evaluation, and conclusion of the issues at hand [14]. This phase is critical, as errors here can impact the accuracy of subsequent research stages. In this study, data from prior research and the Faculty of Agriculture at Kuantan Singingi Islamic University are used to develop the monitoring system. These data provide valuable insights, serving as the foundation for creating a more accurate and efficient rainfall monitoring system [15].

3. RESULTS AND DISCUSSIONS

The proposed system seeks to modernize and enhance the accuracy and efficiency of rainfall measurement by replacing traditional manual methods with an Internet of Things (IoT)-based solution. This system incorporates key components such as a tipping bucket rain gauge for rainfall measurement, an ESP32 or ESP8266 microcontroller for data processing and transmission, and a Wi-Fi module to enable real-time data transfer to a cloud-based platform. The collected data can then be accessed and analyzed through web or mobile applications, providing easy access to vital rainfall information.

a. **Real-Time Monitoring and Continuous Data Collection**

One of the main advantages of the proposed system is its ability to automatically and continuously measure rainfall. Unlike traditional methods that collect data manually at fixed intervals, IoT-based systems allow for real-time monitoring of weather conditions. This ensures more frequent and timely data collection, enabling faster responses to extreme weather events like heavy rainfall or flooding. With real-time data, stakeholders such as farmers, emergency management agencies, and water resource managers can make informed decisions, including issuing early warnings or preparing for potential floods [16].

b. **Accessibility and Reduced Data Limitations**

Another significant benefit of IoT technology is the ability to access rainfall data remotely. Traditional rainfall measurement systems are usually limited to specific locations, restricting data collection to the immediate vicinity of the device. In contrast, IoT-based systems transmit data over the internet, allowing it to be accessed from anywhere with an internet connection. This enhances accessibility, particularly in remote areas, and ensures that valuable rainfall data is available to a broader audience, including researchers, farmers, and disaster management agencies [17].

c. **Increased Accuracy and Reduced Human Error**

Manual rainfall measurement systems are susceptible to human error, such as inaccuracies in readings due to subjective observations, incorrect data interpretation, or mistakes in recording. The proposed IoT-based system addresses these issues by utilizing automatic sensors to collect and log rainfall data.

By employing tipping bucket rain gauges, which measure rainfall at fixed intervals, the system ensures consistent and precise readings without requiring manual input. This automation significantly improves the accuracy of rainfall measurements and minimizes errors, ultimately enhancing the reliability of the collected data [18].

d. **Cloud-Based Data Analysis and Reporting**

A notable feature of the proposed system is its cloud-based platform, which facilitates automated data analysis and the generation of reports or visualizations. In traditional systems, data is manually collected, entered into spreadsheets, and analyzed by human operators, a process that is both time-consuming and prone to mistakes. In contrast, the IoT-based system automates data analysis in real-time, enabling faster insights. Automated reporting, including graphical representations like charts and tables, saves time and resources, allowing for more efficient decision-making. This makes it easier for users to identify trends, patterns, and potential risks associated with rainfall events [19].

e. **Early Warnings and Disaster Preparedness**

A major advantage of the proposed IoT-based system is its ability to detect high rainfall levels and automatically send alerts to stakeholders. This early warning feature is vital for disaster preparedness, particularly in flood-prone regions. When heavy rainfall is detected, the system can trigger alerts, giving communities, emergency responders, and authorities more time to take preventive actions, such as evacuations, deploying resources, and implementing flood mitigation strategies. These measures help reduce the impact of natural disasters like floods [20].

f. **Electronic Circuits**

In the circuit, WeMos D1 R1 connects to the PIR sensor, which detects motion, while resistors control the LED indicators for PIR sensors 1 and 2. A buzzer serves as an alarm. The ESP32 or ESP8266 microcontroller processes data from the rain sensor, calculating total rainfall based on received impulses. It transmits this data in real-time via Wi-Fi to a cloud-based platform or web/mobile applications, enabling users to access rainfall data from any device. The data is stored in the cloud for analysis, producing reports or visualizations like graphs and tables. This real-time monitoring improves decision-making for disaster mitigation, irrigation planning, and water resource management by providing accurate, automated rainfall data [21]. The microcontroller also manages sensor parameters and generates reports, reducing manual processing and saving time. Additionally, if rainfall exceeds a set threshold, the system can trigger alerts for early warnings and better resource management.

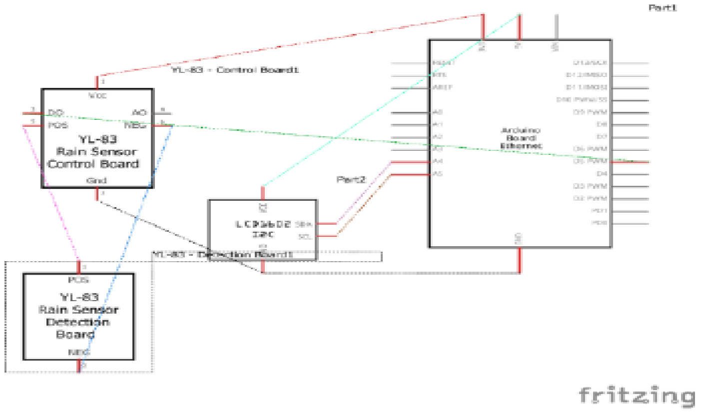

Figure 1: Electronic Circuits

g. Flow Chart How it Works

Work Steps

Before the system becomes operational, the preparation phase includes the following steps to ensure all necessary components are ready [23]:

1. **Rainfall Sensor (Tipping Bucket Rain Gauge):** Install the sensor in an appropriate location, ensuring it is functioning properly.
2. **Microcontroller (ESP32 or ESP8266):** Prepare the microcontroller with a stable Wi-Fi connection and load a program that processes data from the sensor.
3. **Wi-Fi Module:** Connect the microcontroller to a Wi-Fi module (like ESP8266 or ESP32) to enable data transmission to the IoT platform.

4. **IoT Platform:** Set up a cloud-based IoT platform (e.g., Thing Speak, Blynk, or Adafruit IO) to store and display the rainfall data sent from the microcontroller.
5. **Sensor Placement:** Position the tipping bucket rain gauge in an unobstructed location for optimal rainfall measurement.
6. **Sensor Calibration:** Calibrate the sensor to ensure accurate readings, confirming that each bucket movement counts as one correct rainfall measurement unit.
7. **Wiring:** Connect the rainfall sensor to the microcontroller (e.g., using the digital input pins on the ESP32 or ESP8266).
8. **Microcontroller Setup:** Program the microcontroller to interpret the sensor signal (tipping bucket) and convert it into rainfall measurements (mm per drop).
9. **Sensor Data Processing:** Program the microcontroller to count the drops and convert them into rainfall data over specific time intervals (e.g., hourly or daily).
10. **Data Transfer to IoT Platform:** Program the microcontroller to transmit the rainfall data in real-time to the IoT platform via Wi-Fi for monitoring and analysis.
11. **Registration and Configuration:** Register the device on the IoT platform and configure it to receive data from the microcontroller.
12. **Visualization Creation:** Set up the platform to display the data in an easily understandable format, such as graphs or tables.
13. **Alert Creation:** Configure rainfall thresholds (e.g., 50 mm per hour) to trigger early warnings and notifications on the IoT platform.
14. The microcontroller then sends the processed rainfall data, either in numeric or JSON format, to the IoT platform via Wi-Fi. This data is stored in the cloud for further analysis.
15. **Real-Time Data Access:** Users can access the rainfall data through the IoT platform's web or mobile interface.

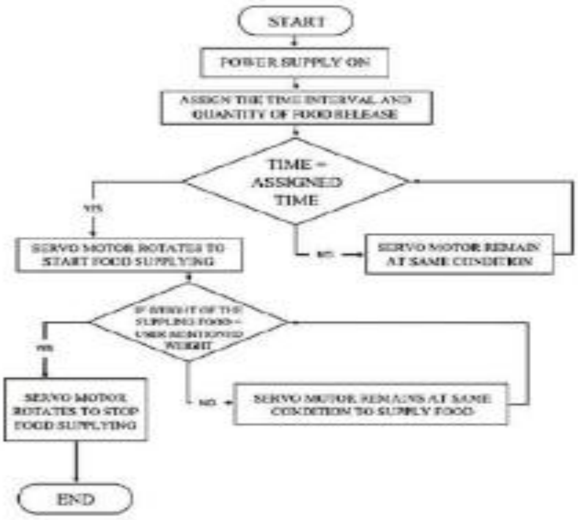

Figure 2: Flow Chart how it Works

User Interface

Arduino IDE (Integrated Development Environment) is an open-source platform used to program Arduino microcontrollers. The main interface consists of several key components. At the top, a toolbar includes buttons for uploading code, saving projects, and selecting the USB port for the microcontroller. Below, the code editor allows users to write and edit programs with features like syntax highlighting, autocompletion, and basic debugging tools [24]. The serial communication console at the bottom displays information from the microcontroller, enabling easy data exchange between the microcontroller and computer [25]. The IDE also includes a library manager for adding external sensor and module libraries. The menu bar offers options for managing projects, selecting hardware, and uploading code, while the status bar displays information such as connected ports and remaining memory. This user-friendly interface simplifies coding and project development for Arduino-based applications.

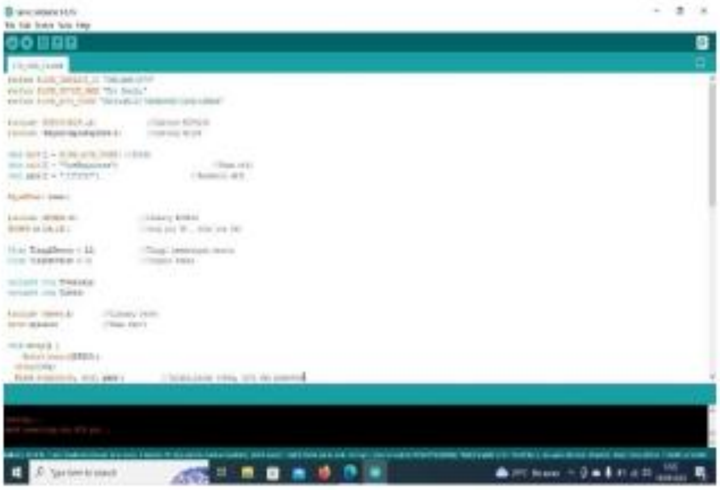

Figure 3: Arduino Editor View

Arduino Circuit

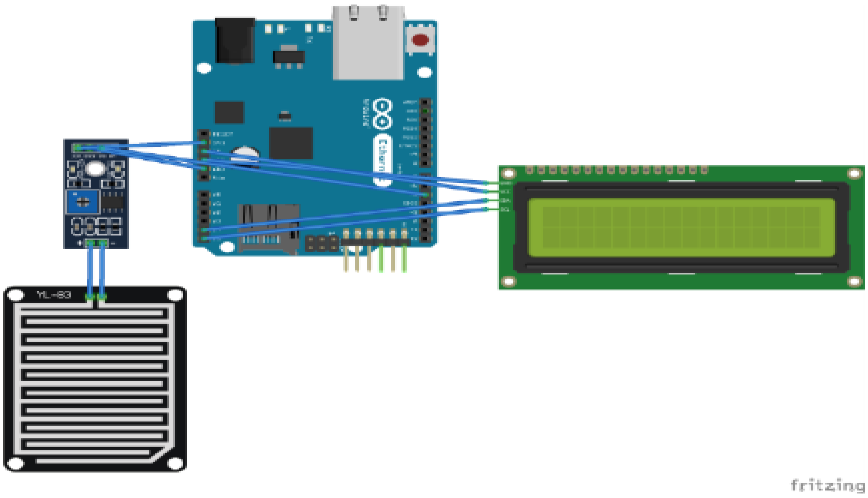

Figure 4: Arduino Circuit

The Arduino Uno collects and processes data from the sensor using pre-programmed code. It transmits the rainfall data to a computer via USB or through a communication module like Wi-Fi for real-time monitoring. With additional components like a Wi-Fi module, Arduino Uno can send data to the cloud, enabling users to access the information through web or mobile applications. In this setup, Arduino Uno serves as the central controller, processing rainfall data and generating reports or visualizations. This makes the Arduino Uno-based rain sensor circuit valuable for applications such as weather monitoring, flood mitigation, and irrigation management [26].

Schematic Circuit

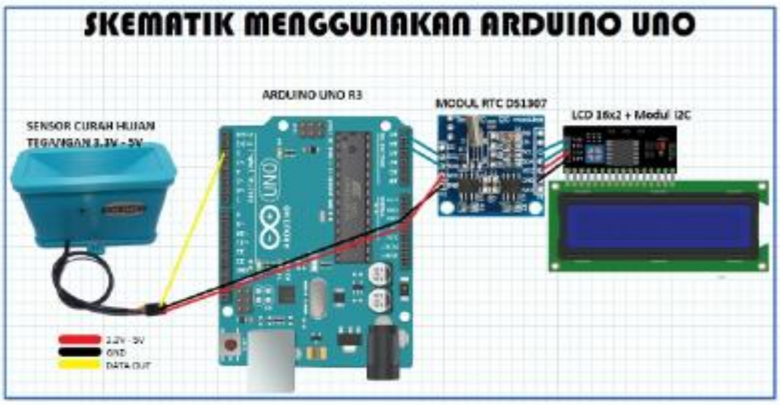

Figure 5: Arduino schematic circuit

Figure 6: Rain Gauge

4. CONCLUSION

This research successfully developed a microcontroller-based rainfall intensity measurement system integrated with Internet of Things (IoT) technology, offering a more efficient, accurate, and real-time solution than traditional manual methods. Utilizing a tipping bucket rainfall sensor, a microcontroller (ESP32 or ESP8266), and a cloud platform, the system can automatically monitor rainfall and transmit data directly to web or mobile applications for analysis. Its main advantage lies in providing real-time rainfall data, enabling faster and more precise weather monitoring. Additionally, the system offers early warnings when rainfall exceeds a certain threshold, which can be crucial for disaster mitigation, agricultural planning, and natural resource management. However, challenges such as dependence on stable internet connectivity, continuous electricity supply, and sensor maintenance must be addressed for optimal performance. Despite these challenges, the system holds significant potential to replace manual systems and provide valuable benefits in weather monitoring, disaster response, agriculture, and natural resource management. This study highlights how IoT technology can enhance rainfall data collection, offering improved efficiency, accuracy, and remote accessibility for monitoring and analysis.

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