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Design of Rainfall Intensity Measuring Instrument Using IoT-Based Microcontroller

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ABSTRACT

The design of a rainfall intensity measuring device utilizing an Internet of Things (IoT)-based microcontroller aims to offer a more precise, efficient, and real-time solution for rainfall measurement compared to the traditional manual systems. While manual systems are still commonly used, they have significant limitations, including reliance on human observation, slow response times, and measurement inaccuracies. In this study, the designed tool incorporates a tipping bucket rain sensor connected to an ESP32 or ESP8266 microcontroller and a Wi-Fi module to transmit real-time data to a cloud-based IoT platform. The collected data is processed and visualized through graphs accessible via web or mobile applications. This system facilitates continuous rainfall monitoring and provides fast, accurate information that can be applied to disaster mitigation, agricultural planning, and natural resource management. By leveraging IoT technology, this system addresses the shortcomings of manual methods, offering considerable benefits for more timely and data-driven decision-making[1].

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1. Introduction

Rainfall is a natural occurrence that has a significant impact on various sectors of life, such as agriculture, water resource management, urban planning, and disaster prevention. Accurate measurement of rainfall intensity is essential for understanding weather patterns, predicting floods, and supporting sustainable environmental management[2]. It helps in planning and managing resources effectively, ensuring water availability, preventing flood risks, and making informed decisions for urban development[3]. However, in many regions, traditional rainfall measurement instruments are often insufficient due to limitations in both the number of devices available and the outdated or inadequate technology used. These conventional systems may not provide real-time data, leading to delays in responses to weather-related events and affecting the accuracy of forecasts and disaster preparedness[4].

IoT (Internet of Things) technology has become a key innovation in various fields, especially in weather monitoring. IoT allows devices to connect and transmit data in real-time, making it possible to access and monitor information from remote locations. In the context of rainfall measurement, IoT technology, when combined with microcontrollers, offers significant opportunities to develop more accurate, efficient, and cost-effective measurement instruments[5]. By integrating IoT, sensors can collect real-time rainfall data and transmit it to cloud-based platforms, enabling continuous monitoring and faster decision-making for applications like flood forecasting, agriculture, and water resource management. This integration reduces reliance on manual measurements and outdated methods, ensuring greater accuracy and efficiency in capturing rainfall data[6].

Using a microcontroller, rainfall data can be automatically collected, processed, and transmitted via the internet to a platform for data storage and analysis. This approach not only makes monitoring rainfall more convenient but also facilitates the rapid dissemination of data, which is crucial for decision-making processes such as flood early warnings and irrigation planning[7]. Therefore, this study focuses on designing and developing an IoT-based rainfall intensity measuring instrument that incorporates a microcontroller. The objective is to provide a more efficient, cost-effective, and real-time solution for both communities and agencies that rely on accurate rainfall data for planning and resource management[8].

Rainfall refers to the amount of rainwater that falls to the Earth's surface over a given period, typically measured in millimeters (mm) or inches (in). Various methods and tools are employed to measure rainfall. One of the most commonly used methods is the Pluviometer (rain gauge), a simple instrument that collects rainwater and measures the volume based on the water level in the container[9]. Another approach is the use of Automatic Weather Stations (AWS), which are equipped with rainfall sensors that automatically measure rainfall and transmit data via wireless connections or the internet to data collection centers. These stations often include weather radar systems, which use signals reflected by water droplets to monitor rainfall patterns in real-time. Satellite data also plays a crucial role in estimating rainfall over large areas. Additionally, hydrometers are used to measure raindrop sizes, helping estimate rainfall amounts[10]. Combining these methods enhances the accuracy of rainfall measurement in a region. Establishing a wide network of weather stations is vital for effective rainfall monitoring, particularly for disaster prevention and water resource planning[11].

All of the methods mentioned utilize weather forecasting techniques to predict future rainfall, enabling the collected data to be applied for agricultural purposes. These rainfall estimates can be used across Indonesia. In specific areas of Kuantan Singingi Regency, rainfall data is gathered using Pluviometer tubes placed at food crop offices in each sub-district, alongside data from weather forecast satellites. The water collected in the pluviometer tubes is measured after rainfall events, and the data is then collected, stored, and analyzed for further use[12].

The Arduino microcontroller is an open-source device designed to support the development and control of electronic systems across various applications. It is highly suitable for use in rainfall measurement tools, allowing real-time display of rainfall data, while also storing the collected data in a database for easy access and further utilization[13].

2. Research Method

In this study, the methods used are:

1. Field Research

Research conducted by conducting observations in the field so that simulations can be carried out on the system created, this research can be done in the following ways:

a. Interview

That is, a method of collecting data and a way of holding direct questions and answers, to parties who have authority in the school to get a comprehensive picture of the existing information system. Interviews require important requirements, namely a good and democratic relationship between respondents and questioners. The function of interviews in research is:

1. Obtaining information directly from respondents (primary method)
2. Obtaining information, when other methods cannot be used (secondary method)

b. Observation

That is, a method of collecting data by studying all documents and records containing the required data.

2. Library Research

That is, a method of collecting data carried out by reading and studying books as reference materials related to the problem of compiling this final assignment.

3. Laboratory Research

That is, the author's activities in processing the information obtained, then designing the desired application based on the existing data and information

System analysis is the process of identifying and understanding the problems within the research object to determine appropriate solutions. It allows researchers to assess, evaluate, and draw conclusions about the issues at hand[14]. This stage is essential because any errors made here can affect the accuracy and reliability of subsequent stages in the research. In this study, data collected from previous research, as well as data obtained from the Faculty of Agriculture at Kuantan Singingi Islamic University, serves as a reference for developing the monitoring system. These data sets provide valuable insights for understanding the research problem and forming a foundation for the system's development. The data can then be processed and used to create a more accurate and effective rainfall monitoring system. By relying on this collected data, the system can be designed to offer real-time rainfall measurement and ensure that the information is stored in a database for easy access and future use. Ultimately, the system analysis helps ensure the development of a reliable and efficient tool for rainfall monitoring[15].

3. Result and Discussion

The proposed system aims to replace traditional manual methods of rainfall measurement with a more modern, accurate, and efficient Internet of Things (IoT)-based solution. The system integrates key components such as a tipping bucket rain gauge for measuring rainfall, an ESP32 or ESP8266 microcontroller to process and transmit data, and a Wi-Fi module to facilitate real-time data collection and transmission to a cloud-based platform. Once data is collected, it can be accessed and analyzed via web or mobile applications, providing seamless access to critical rainfall information.

a. Real-Time Monitoring and Continuous Data Collection

One of the key advantages of the proposed system is its ability to measure rainfall automatically and continuously. Unlike traditional methods, where data is collected manually and at fixed intervals, IoT-based systems enable real-time monitoring of weather conditions. This means that rainfall measurements are taken continuously, providing more frequent and timely data. In turn, this allows for a faster response to extreme weather events, such as heavy rainfall or potential flooding. With real-time data, relevant stakeholders, including farmers, emergency management agencies, and water resource managers, can make more informed decisions, such as 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 often confined to specific physical locations, meaning data collection is limited to the device's immediate vicinity. In contrast, IoT-based systems transmit data over the internet, eliminating the need for on-site presence and allowing data to be accessed from anywhere with an internet connection. This enhances accessibility, particularly in remote or hard-to-reach areas, and ensures that valuable rainfall data is not confined to specific locations, but rather made available to a wider range of users, including researchers, farmers, and disaster management agencies[17].

c. Increased Accuracy and Reduced Human Error

Manual rainfall measurement systems are prone to human error, such as inaccurate readings due to subjective observation, incorrect interpretation of data, or mistakes in data recording. The proposed IoT-based system minimizes these human errors by relying on automatic sensors to collect and record rainfall data. The use of tipping bucket rain gauges, which measure rainfall based on a fixed interval, ensures precise and consistent readings without the need for manual input. This automation increases the accuracy of rainfall measurements and reduces the likelihood of errors, which ultimately enhances the reliability of the data collected[18].

d. Cloud-Based Data Analysis and Reporting

A key feature of the proposed system is its cloud-based platform, which allows for automated data analysis and the generation of reports or visualizations. In traditional systems, data is often collected manually, entered into spreadsheets, and analyzed by human operators, a process that is time-consuming and prone to errors. In contrast, the IoT-based system automates this process, enabling rainfall data to be analyzed in real-time[19]. Automated reporting and graph generation save both time and resources, allowing for quicker insights and more efficient decision-making. For example, rainfall data can be presented in the form of graphs, charts, or tables, helping users better understand trends, patterns, and potential risks associated with rainfall events.

e. Early Warnings and Disaster Preparedness

One of the most significant advantages of the proposed IoT-based system is its ability to detect high rainfall levels and send automatic alerts to relevant stakeholders. This early warning capability is especially crucial for disaster preparedness, particularly in areas prone to flooding. When heavy rainfall is detected, the system can trigger automatic alerts, giving communities, emergency response teams, and authorities more time to prepare and take preventive measures. This can include evacuations, the deployment of emergency resources, and the implementation of flood prevention strategies, all of which contribute to reducing the impacts of natural disasters such as floods[20].

f. Electronic Circuits

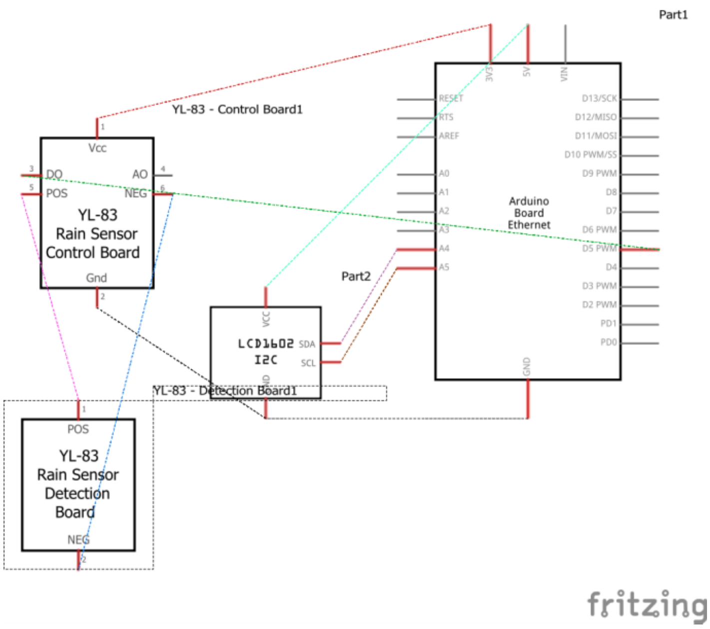

Figure 1. Electronic Circuits

In the circuit above, WeMos D1 R1 is connected to the PIR Sensor which functions as a motion detector input, then there is a resistor as an LED resistance which is used as an indicator for each PIR sensor 1 and 2. There is also a Buzzer that functions as an alarm. 2. Flowchart How it Works.

Microcontrollers, such as ESP32 or ESP8266, are responsible for processing data from the rain sensor and calculating the total rainfall based on the number of impulses received. This microcontroller also sends rainfall data in real time using a Wi-Fi module, so that the data can be sent to a cloud-based platform or web/mobile application. This process allows rainfall data to be accessed from various devices, either via the web or mobile applications. The collected rainfall data is then stored in the cloud and can be analyzed to produce reports or visualizations such as graphs and tables. This information allows users to monitor rainfall intensity more accurately and make decisions based on real-time data. This rain sensor is very useful in various applications, such as disaster mitigation, irrigation planning, and water resource management, because rainfall data that is measured automatically and accurately helps reduce flood risks and supports better decision making[21].

After the data is sent to the cloud, the microcontroller can also process the data to produce reports or visualizations in the form of graphs, tables, or other reports. This process helps reduce the need for manual data processing, making it more efficient and time-saving. Rainfall data that is accessed in real time is very useful for early flood warnings, irrigation management, and better water resource management.

Thus, IoT rain sensors provide advantages in terms of data accuracy, efficiency, and accessibility, which support various important applications such as disaster mitigation and data-driven decision making.

The microcontroller also functions to set sensor parameters, such as measurement duration or tipping frequency, so that the sensor functions optimally and produces accurate data. In addition, the microcontroller can analyze rainfall data and produce reports or visualizations such as graphs and tables to help users understand rainfall trends. In some cases, if rainfall reaches a certain threshold, the microcontroller can send an alert for disaster mitigation or water resource management. Thus, the microcontroller functions as a key component in ensuring that the rainfall measurement system runs efficiently and effectively[22].

g. Flowchart How it Works

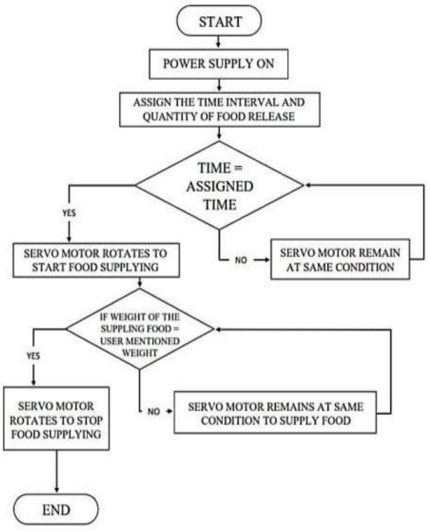

Figure 2. Flowchart How it Works

Work steps

Before the system starts operating, the preparation phase involves collecting and installing the necessary components[23]:

- **Rainfall Sensor** (Tipping Bucket Rain Gauge): Install the rainfall sensor in a suitable location and make sure the sensor is in good condition.
- **Microcontroller** (ESP32 or ESP8266): Prepare the microcontroller and make sure it has a stable Wi-Fi connection. Make sure the microcontroller is equipped with a program to process data from the sensor.
- **Wi-Fi Module**: Connect the microcontroller to a Wi-Fi module (such as ESP8266 or ESP32) so that it can send data to the IoT platform.
- **IoT Platform**: Prepare a cloud-based IoT platform (such as ThingSpeak, Blynk, or Adafruit IO) to store and display rainfall data sent from the microcontroller.
- **Sensor Placement**: Place the tipping bucket rain gauge in an open location that is not obstructed by other objects, such as trees or buildings, so that the falling rain can be measured optimally.
- **Sensor Calibration**: Calibrate the sensor to ensure measurement accuracy. Make sure each tipping bucket movement is counted as one correct rainfall measurement unit.
- **Wiring**: Connect the rainfall sensor to the microcontroller (e.g., using the digital input pins on the ESP32 or ESP8266).
- **Microcontroller Setup**: Program the microcontroller to read the signal from the sensor (tipping bucket) and convert it into the appropriate rainfall data form (mm per drop).
- **Sensor Data Processing**: Program the microcontroller to count the number of drops counted by the sensor, converting the data into rainfall values in millimeters per specific time (e.g., per hour or per day).

- **Data Transfer to IoT Platform**: The microcontroller is programmed to transfer rainfall data to the IoT platform using Wi-Fi. The data is sent in real-time so that it can be monitored and analyzed directly.
- **Registration and Configuration**: Register the device on the IoT platform (e.g., ThingSpeak, Blynk, or Adafruit IO), then set the platform to receive data from the microcontroller.
- **Visualization Creation**: Determine the type of visualization to be used, such as a graph or table, to display the rainfall data received. The platform allows users to view the data in an easy-to-understand format.
- **Alert Creation**: Set rainfall thresholds to provide early warnings. For example, if rainfall exceeds 50 mm in 1 hour, the IoT platform can provide a notification to the user.
- The microcontroller sends the processed rainfall data to the IoT platform using a Wi-Fi connection.
- The rainfall data sent can be in the form of numeric values or in JSON format, which is then stored in the cloud for further analysis.
- **Real-Time Data Access**: Users can access rainfall data directly through the application or web interface provided by the IoT platform.

User Interface

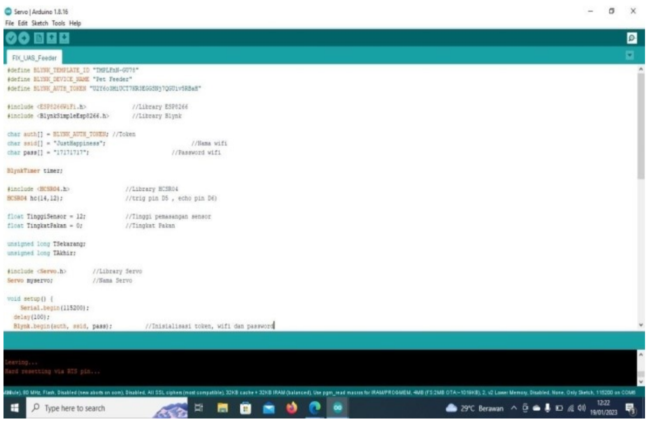

Figure 3. Arduino Editor View

Arduino IDE (Integrated Development Environment) is an open-source development environment used to program Arduino microcontrollers. The main interface of Arduino IDE consists of several important components. At the top of the screen, there is a toolbar that provides navigation buttons such as buttons for uploading code, opening and saving projects, and selecting the USB port where the microcontroller is connected. Below the toolbar, there is a code editor, which is the main area for typing and editing programs. This editor is equipped with features such as syntax highlighting, autocompletion, and simple debugging features to make writing and developing code easier[24].

At the bottom of the editor, there is a serial communication console, where information and messages from the microcontroller are displayed. The serial communication feature allows the microcontroller to talk to the computer, so that data can be sent and received easily[25]. Arduino IDE is also equipped with a libraries manager, which allows users to add libraries needed to support the use of external sensors and modules. At the top, the menu bar contains navigation options such as File, Edit, Sketch, Tools, and Help, which are used to manage projects, select hardware, and upload code. Finally, at the bottom, there is a status bar, which displays important information such as connected ports and the remaining memory of the microcontroller. With this simple and functional interface, the Arduino IDE makes it easy for users to write code and develop various projects based on the Arduino microcontroller.

Arduino Circuit

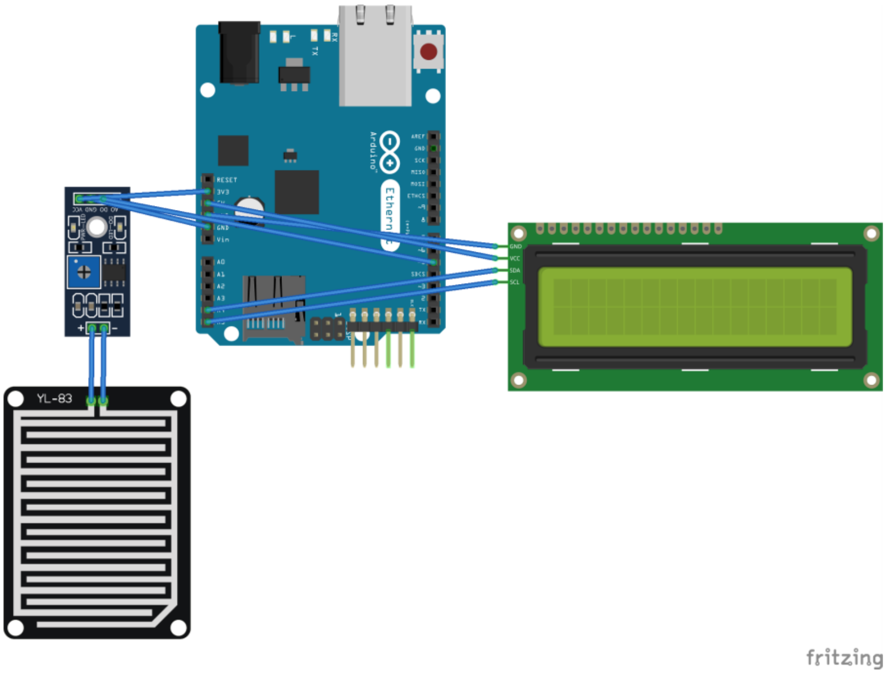

Figure 4. Rain Sensor Circuit

Arduino Uno collects data from the sensor and processes it using pre-compiled code. The rainfall data is transmitted to a computer via USB or through a communication module like Wi-Fi for real-time monitoring. Additionally, Arduino Uno can be enhanced with components like a Wi-Fi module to send data to the cloud, allowing users to access the information through web or mobile applications. In this configuration, Arduino Uno acts as the central controller, efficiently processing rainfall data and facilitating the generation of reports or visualizations. Therefore, the rain sensor circuit using Arduino Uno is highly beneficial for applications such as weather monitoring, flood mitigation, and irrigation management[26].

Schematic Circuit

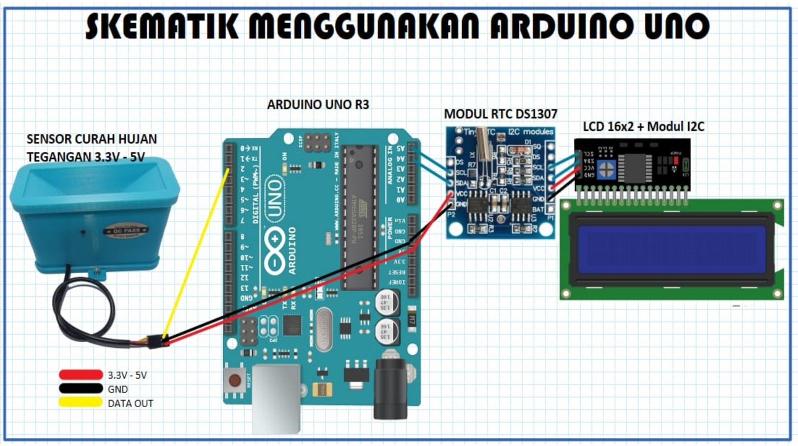

Figure 5. Arduino schematic circuit

Figure 6. Rain Gauge

4. Conclusion

This research has successfully designed and developed a microcontroller-based rainfall intensity measurement system connected to Internet of Things (IoT) technology, offering a more efficient, accurate, and real-time solution compared to the manual methods that have been used so far. By utilizing a tipping bucket type rainfall sensor, microcontroller (ESP32 or ESP8266), and cloud platform, this system can monitor rainfall automatically and send data directly to a web-based or mobile application for further analysis. The main advantage of this system is its ability to provide real-time rainfall data, allowing users to monitor weather conditions more quickly and precisely. In addition, this system can also provide early warnings if rainfall exceeds a certain threshold, which can be an important tool in disaster mitigation, such as flooding, as well as in agricultural planning and natural resource management.

However, there are several challenges that need to be considered in its implementation, such as dependence on the stability of the internet connection and the availability of continuous electricity resources. In addition, sensor maintenance and software updates are also important to maintain the accuracy and smoothness of the system.

Overall, the proposed system has great potential to replace manual systems and provide significant benefits in various applications, both for general weather monitoring, disaster mitigation, and in the agricultural and natural resource management sectors. This study shows that IoT technology can improve the efficiency and accuracy of rainfall data collection, while providing convenience in remote monitoring and analysis.

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