



Design and Development of an Automatic Clothes Drying System Based on Microcontroller

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ABSTRACT

The conventional clothes drying process is highly dependent on weather conditions and often requires continuous human supervision, reducing efficiency and convenience. Unpredictable environmental changes, such as rain, high humidity, or limited sunlight, can negatively affect drying performance and increase drying time. This study aims to design and implement a microcontroller-based automatic clothes drying system that operates independently according to environmental conditions. The system utilizes a microcontroller as the main controller, integrated with temperature and humidity sensors to monitor air conditions and a light sensor to detect sunlight intensity. Sensor data are processed to control the drying mechanism automatically. DC motors and relays function as actuators to adjust the system based on environmental changes. The research methodology includes hardware design, software development, system integration, implementation, and performance testing. The results demonstrate that the system can effectively determine drying actions based on sensor inputs and respond automatically to changing environmental conditions. This system improves drying efficiency, reduces manual intervention, and provides a practical solution for household clothes drying.

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1. Introduction

The advancement of automation technology and the Internet of Things (IoT) has had a significant impact on various aspects of modern human life, including the management of daily household activities [1],[2]. Microcontroller-based automatic control systems are increasingly being applied to improve efficiency, comfort, and reliability in a wide range of activities, from controlling household appliances to monitoring the environment in real time [3],[4]. One household activity that is still widely carried out manually and depends on natural conditions is the process of drying and airing clothes.

The conventional clothes drying process is highly dependent on weather conditions, particularly the availability of sunlight and the absence of rain [5],[6]. Increasing weather uncertainty, including sudden rainfall and unpredictable fluctuations in sunlight intensity, often causes clothes to become wet again or the drying process to become suboptimal [7],[8]. This situation not only wastes time and energy, but also disrupts user productivity, especially for those who are frequently active away from home. Therefore, the

need for a system capable of operating independently without manual supervision has become increasingly urgent [9],[10].

Various studies have been conducted to develop automatic clothes drying systems by utilizing electronic components such as the Arduino Uno microcontroller, rain sensors, and light sensors (LDR) [11],[12],[13]. These studies have demonstrated that microcontroller-based systems are capable of detecting changes in environmental conditions and automatically moving the drying mechanism, thereby reducing users' dependence on manual supervision [14],[15]. However, most systems developed in previous research are still limited to the function of opening and closing the drying roof based solely on rain detection, without integrating an active drying process when clothes are indoors [16].

In the development of microcontroller-based automatic systems, selecting the appropriate sensors is a key factor for system success. Rain sensors are used to detect the presence of rainwater and send a signal to the microcontroller to respond automatically [17]. LDR (Light Dependent Resistor)-based light sensors function to detect sunlight intensity as an indicator of bright or dark weather conditions [18],[19]. Meanwhile, the DHT11 temperature and humidity sensor enables real-time monitoring of air conditions inside the drying chamber, so that the system can determine when the active drying process needs to be activated or stopped [20],[21].

The advancement of IoT technology has driven the emergence of a new generation of smart drying systems that can be controlled and monitored remotely via smartphone-based applications or web platforms [22],[23]. Several studies have integrated Wi-Fi modules such as NodeMCU ESP8266 and ESP32 into automatic clothes drying systems, enabling users to receive real-time notifications and perform remote control through applications such as Blynk [24]. Nevertheless, most existing IoT implementations in clothes drying systems have not yet combined an active drying mechanism based on heaters and fans within a single integrated control system that operates independently based on comprehensive temperature and humidity parameters [25].

Based on a review of previous studies, there is a gap that needs to be addressed, namely the development of an automatic clothes drying system that integrates rain sensors, light sensors, and temperature and humidity sensors within a single comprehensive microcontroller control platform. This study aims to design and develop such a system using an Arduino Uno microcontroller as the central control unit integrated with three types of environmental sensors and actuators in the form of a DC motor, relay, heating element, and DC fan. The main contribution of this research is to present an integrated automatic control system capable of adaptively regulating the drying process according to environmental conditions, thereby improving the efficiency, reliability, and user comfort in the daily clothes drying process.

2. Research Method

2.1 Type and Approach of Research

This study uses an engineering research method with a system design and development approach. This method aims to design, implement, and test the performance of a microcontroller-based automatic clothes drying system. The research focuses on hardware and software development as well as evaluation of system function based on environmental conditions.

2.2 System Design

The system design is carried out in stages, including hardware design and software design. The system is designed to operate automatically based on inputs from environmental sensors and display system condition information through an LCD screen.

2.2.1 Prototype Design

Prototype design was carried out to realize the concept of the automatic clothes drying system into a physical form that can be tested. The prototype was designed with consideration of component layout, drying mechanism, and drying system so that all components can work optimally and in an integrated manner.

At this stage, the mechanical design of the clothesline was carried out, including the placement of rain sensors, light sensors, and temperature and humidity sensors in appropriate positions to obtain accurate environmental data. In addition, actuators such as DC motors, heating elements, and fans were installed on the prototype according to their functions. The prototype was also equipped with an LCD screen as an information medium to display the temperature in the drying chamber in real time.

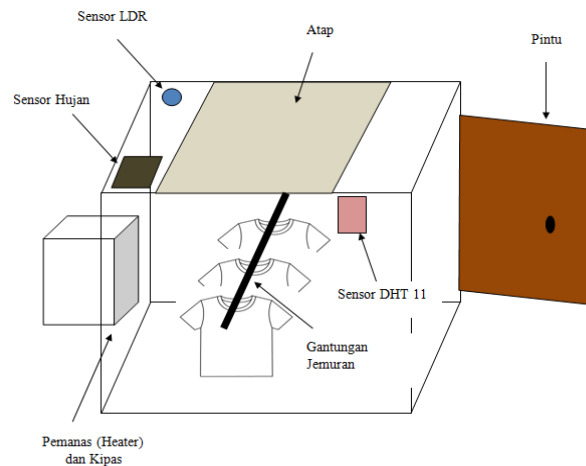


Figure 1. Prototype Design

2.2.2 Hardware Design

The system hardware consists of several main components that work together to create an automatic clothes drying system. The core component is the Arduino Uno microcontroller, which serves as the main control unit responsible for processing sensor data and controlling all system operations. The microcontroller receives input from various sensors, analyzes environmental conditions, and sends commands to the actuators to ensure the drying process operates efficiently. Several sensors are integrated into the system to monitor environmental parameters. A rain sensor is used to detect the presence of rain or water droplets, enabling the system to take appropriate actions when unfavorable weather conditions occur. A Light Dependent Resistor (LDR) functions as a light sensor to measure sunlight intensity. This sensor helps determine whether natural sunlight is sufficient for the drying process. Additionally, a DHT11 temperature and humidity sensor is employed to monitor air temperature and humidity levels. These measurements are important for maintaining optimal drying conditions and improving system performance.

The system also utilizes several actuators to perform the required mechanical and electrical operations. A DC motor is used to drive the drying mechanism according to commands from the microcontroller. A relay module acts as an electronic switch that allows the microcontroller to control high-power devices safely. Through the relay, the system can activate or deactivate a heating element and a DC fan. The heating element provides additional heat to accelerate the drying process, especially during cloudy or humid conditions, while the DC fan improves air circulation and helps reduce moisture inside the drying chamber. To provide real-time information to users, an LCD screen is included in the system design. The display shows temperature data measured by the DHT11 sensor, allowing users to monitor conditions inside the drying chamber. Overall, the integration of these hardware components enables the system to automatically detect environmental changes, control the drying process, and improve drying efficiency with minimal human intervention. This hardware configuration supports the development of a practical and intelligent clothes drying solution for household applications..

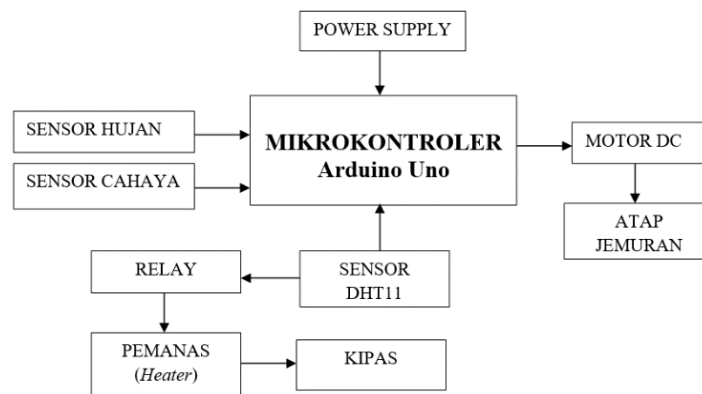


Figure 2. System Design Block Diagram

2.2.3 Software Design

The system software is developed using the C programming language on the Arduino IDE platform. The program is designed to read data from rain sensors, light sensors, and temperature and humidity sensors. The data is then processed using control logic to determine clothes drying and drying conditions. Based on the data processing results, the microcontroller controls the DC motor, relay, and displays temperature information on the LCD screen.

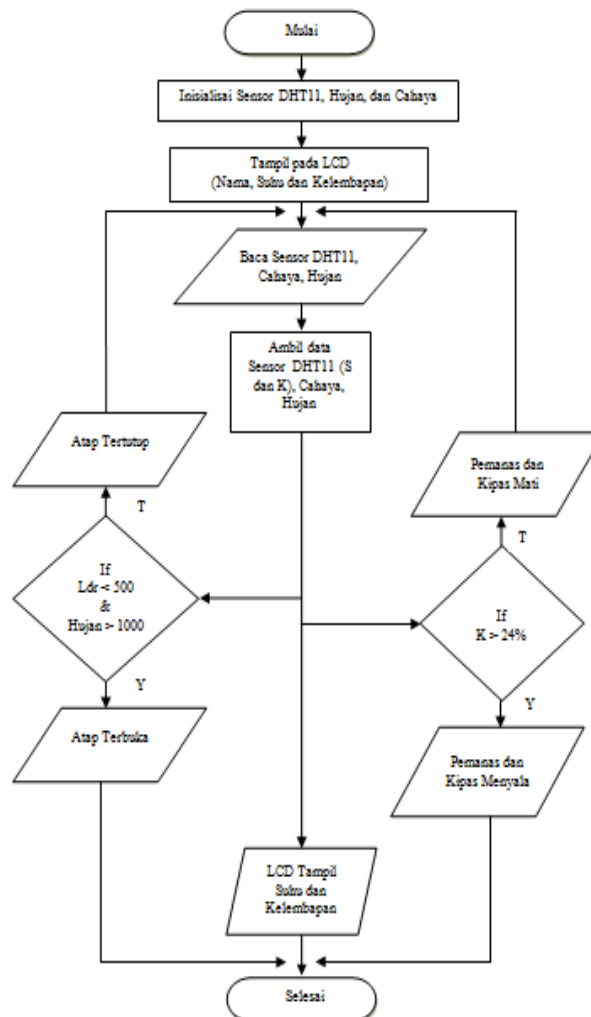


Figure 3. Program Flowchart

2.3 System Workflow

The system workflow begins with the initialization of all hardware components. Next, the system continuously reads data from environmental sensors. If the rain sensor detects rain, the system automatically closes the drying roof and activates the drying system. If there is no rain and light intensity is sufficient, the system opens the drying roof for natural drying. Temperature and humidity sensors are used to monitor the condition of the drying chamber, while the temperature value is displayed on the LCD screen as information for the user.

2.4 System Testing Method

System testing is conducted to ensure that all components work according to the design. Testing includes sensor testing, actuator testing, and overall system testing. Sensors are tested to ensure the accuracy of environmental condition readings, while actuators are tested to ensure the mechanical response runs according to microcontroller commands. System testing is conducted by simulating various environmental conditions, such as rain, bright conditions, and humid conditions, to observe the automatic system response.

3. Result and Discussion

3.1 Hardware Design Results and System Implementation

The results of this study are a prototype of a microcontroller-based automatic clothes drying system that has been implemented and tested. The system consists of a rain sensor, light sensor, temperature and humidity sensor, DC motor actuator, relay, heater, fan, and LCD screen as a medium for displaying drying chamber temperature information.

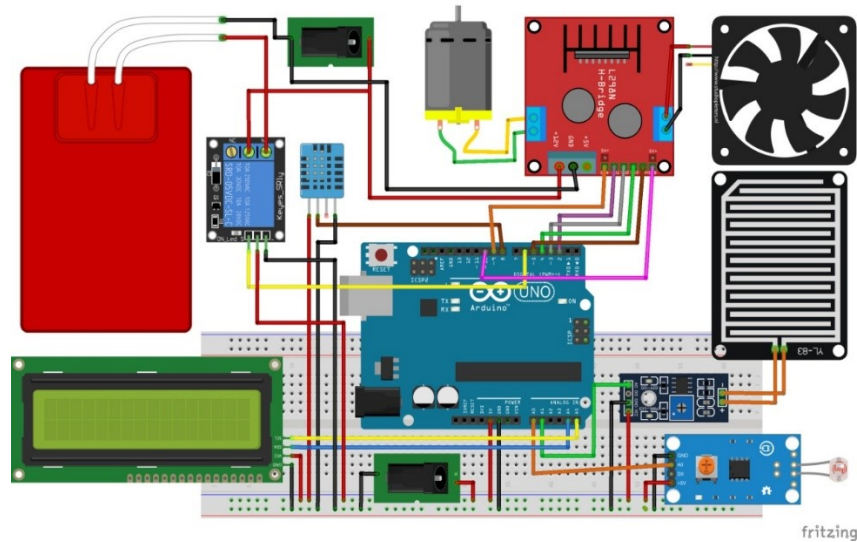


Figure 4. Hardware Prototype Wiring/Schematic Diagram

3.2 Temperature and Humidity Sensor Test Results

Temperature and humidity sensor testing was conducted to determine the stability of sensor readings as the basis for controlling the drying system. The DHT11 sensor test results are shown in Table 1. Based on the test results, the sensor was able to provide relatively stable temperature and humidity values in accordance with the environmental conditions of the drying chamber. The temperature data read by the sensor was displayed in real time on the LCD screen.

Table 1. Temperature And Humidity Sensor Test Results Under Various Room Conditions

Initial Room Condition		Room Condition with Dry Clothes		Room Condition with Wet Clothes	
Temperature	Humidity	Temperature	Humidity	Temperature	Humidity
32°C	51%	32°C	53%	32°C	76%

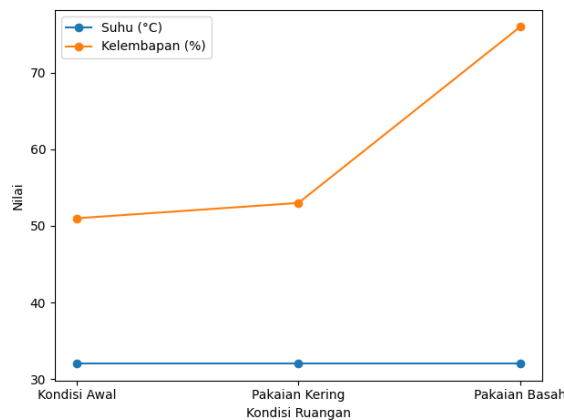


Figure 5. Graph of Temperature and Humidity Sensor Test Results Under Various Room Conditions

Based on Table 1 and Figure 5, the room temperature in all test conditions was at the same value of 32°C. In contrast, the humidity values showed significant changes, from 51% in the initial condition to 53% in the dry clothes condition, and sharply increased to 76% in the wet clothes condition. This indicates that clothes conditions affect humidity more than temperature, making the humidity parameter the main indicator in controlling the clothes drying system.

3.3 Light Sensor and Rain Sensor Test Results

Light sensor testing was conducted to determine the system's ability to differentiate between bright and dark conditions. The light sensor test results are shown in Table 2, indicating that changes in light intensity affect the system's decision to open or close the drying roof. Rain sensor testing was conducted by simulating water on the sensor surface. The test results show that the system can detect rain and automatically close the drying roof and activate the drying system.

Table 2. Rain Sensor And Ldr Sensor Simulation Test Results

Weather Condition	LDR Sensor Active	LDR Sensor Inactive	Rain Sensor Active	Rain Sensor Inactive	DC Motor
Sunny, No Rain	✓	-	-	✓	Roof Open
Sunny, Raining	✓	-	✓	-	Roof Closed
Dark, Raining	-	✓	✓	-	Roof Closed
Dark, No Rain	-	✓	-	✓	Roof Closed

3.4 Actuator Test Results

Actuator testing includes testing of the DC motor, relay, heating element, and fan. The actuator test results are shown in Figure 9. The DC motor was able to move the drying roof mechanism according to system commands, while the relay worked well in controlling the heater and fan. This indicates that the actuators can respond to microcontroller commands optimally.



Figure 6. Room Heater Test



Figure 7. (a) Initial temperature and humidity state when wet clothes are inserted,
(b) Temperature and humidity state after 3 minutes

3.5 Discussion

Based on the test results, the automatic clothes drying system is able to work according to the design. The integration of environmental sensors allows the system to make decisions automatically based on actual field conditions. The addition of an active drying system and temperature display through the LCD is an advantage of this system compared to conventional automatic dryers that only rely on weather conditions.

4. Conclusion

Based on the results of the design, implementation, and testing conducted, it can be concluded that the microcontroller-based automatic clothes drying system was successfully designed and functioned according to the research objectives. The system can respond to changing environmental conditions automatically through the integration of rain sensors, light sensors, and temperature and humidity sensors.

The test results show that environmental sensors and actuators work well and are able to support system decision-making in the clothes drying process. The system can automatically open and close the drying roof and activate the drying system when weather conditions do not support natural drying. Temperature information in the drying chamber displayed through the LCD screen provides convenience for users in monitoring the drying process in real time.

Thus, the developed system is able to improve the efficiency and reliability of the clothes drying process compared to conventional methods that depend on weather conditions and manual supervision. This system is expected to be an alternative solution in the application of simple automation technology for household needs.

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