Household automatic clothes dryer with temperature control

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ABSTRACT

Problems arising from the impact of irregular weather changes on the process of drying clothes, especially jeans, are an obstacle for housewives. Commercial clothes dryers are expensive and can cause fabric damage. Cleanliness and dryness of clothes play a vital role in everyday life. This article offers a solution in the form of an automatic clothes dryer with a temperature controller using the Arduino Uno microcontroller. This tool has a humidity sensor, LCD screen, indicator light, heater, fan, and DC motor. When the humidity is high, the tool automatically activates the heater, fan, and red indicator light. After the drying process is complete, the green indicator light turns on, indicating that the clothes are dry. This study aims to develop other similar research by designing a clothes dryer control system based on Arduino Uno. Experiments show that this dryer is more efficient, taking 80 minutes compared to 240 minutes of manual drying in the sun. The humidity setting at 20 HR is the set point to ensure an optimal drying process. The contribution of this research lies in the development of efficient clothes dryer technology that can be implemented practically.

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1. INTRODUCTION

Irregular weather changes make housewives work, especially with wet and dry clothes, a problem in itself [1]-[3]. Wet clothes do not dry quickly because the drying process that only relies on the heat of the sun causes the drying process of clothes to be slow [4]-[6]. Although washing machines help clean clothes, their built-in drying function cannot solve the problem [7]-[9]. One of the most difficult clothes to dry is jeans [10]-[12].

Generally, clothes dryers sold on the market are dryers that are made in one package with a washing machine, so the price of washing machines is very expensive, especially for the lower middle class [13]-[15]. Another negative effect of this tool is the result of drying clothes in the dryer, which turns out to cause clothes to be damaged quickly [16]-[19]. These side effects are caused by clothes that are too tight [20]-[22].

The problem is very important to immediately get a solution, because the durability of clothing is everyone's desire. This research is important to do because it will provide a new solution to the problem. Fast drying, safe for clothing and its users is what is needed today.

The application of technology in this field was previously implemented by Gifari *et al.* in 2021 [23], entitled "Design and Implementation of Clothesline and Air Dryer Prototype Base on the Internet of Things." This research used an Arduino Nano microcontroller and a fan as the dryer. Mila *et al.* [24] created an automatic clothes drying monitoring and information system based on NodeMCU ESP8266 (IoT) with a more efficient and practical clothes drying management concept. Another research conducted by Pinem *et al.* [25] entitled “Automatic Control Circuit Design for a Clothes Dryer” was designed using ESP32 and a fuzzy logic controller that can be controlled remotely using an Android device.

This study is different from the three previous studies, this study fully controls the heater in drying clothes by determining the maximum and minimum range of the type of fabric so as not to damage it and the drying process can be carried out optimally. Temperature detection uses a sensor that can detect responsively and an Arduino Uno microcontroller as the process control of the tool.

2. METHOD

The stages in this study are collecting data on each component, designing hardware, and creating software to create a clothes dryer. The method used in this study is designing tools and experiments. In the system design, there is a DHT11 sensor which is used to detect the temperature and humidity of the clothes dryer. This device also contains a heater which is used to add heat. After that, there is air ventilation to remove humid air inside. With this output, the actuator will be coordinated so that the clothes drying process is appropriate and detected by the sensor. This system uses an Arduino Uno as a controller with threshold settings. The DHT11 sensor sends data to Arduino Uno where the data will be processed sequentially in the clothes dryer production.

2.1. System flowchart

The design of a clothes dryer with a temperature controller based on Arduino Uno has hardware that supports its operation. The block diagram can be seen in Figure 1.

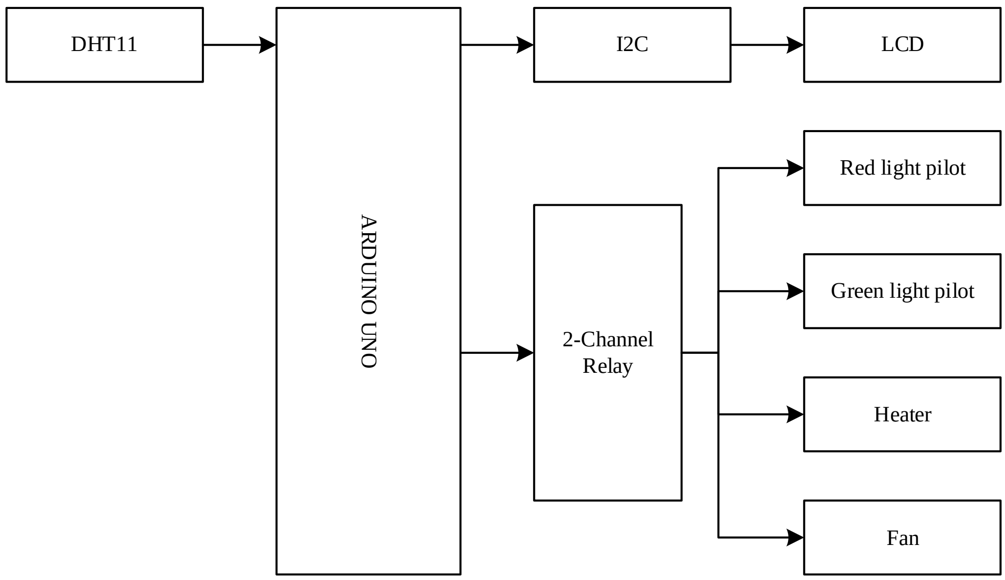

Figure 1. Schematic diagram of a system

The explanation of the block diagram above is as follows:

a. DHT11 sensor is used to detect temperature and humidity in the clothes dryer machine.
b. Arduino Uno is used as a controller for the entire system.
c. I2C is used as a way to simplify the pins on the LCD.
d. LCD screen displays humidity data on the tumble dryer.
e. A 4-channel relay turns on the red pilot light, green pilot light, heater, and fan.
f. The red pilot light is used to indicate that the laundry is damp/not yet dry.
g. The green pilot light is used to indicate that the clothes are dry.
h. The heater is used in the clothes drying process.
i. The blower/fan is used as a wind in the clothes drying process with specifications of 12 volts and 6.2 Amps.

2.2. Clothes dryer temperature control system block diagram

The block diagram is made to facilitate the research completion process. Thus providing an overview of the relationship between various components' input, process, and output parts. Figure 2 shown a block diagram of a one-way system.

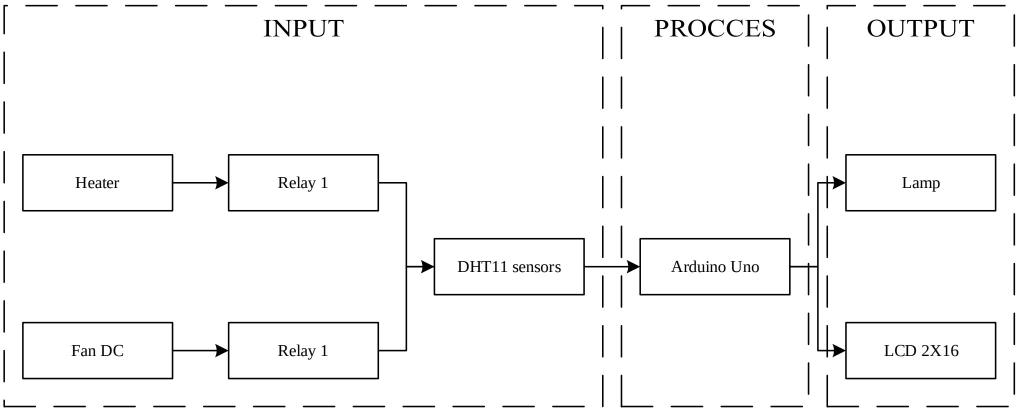

Figure 2. Block diagram of clothes dryer temperature control system

Before entering the realization stage, it is necessary to understand the working system of the tool to be made, so that the implementation of the design can be arranged as desired. Figure 3 is a flow diagram of the tool's working system.

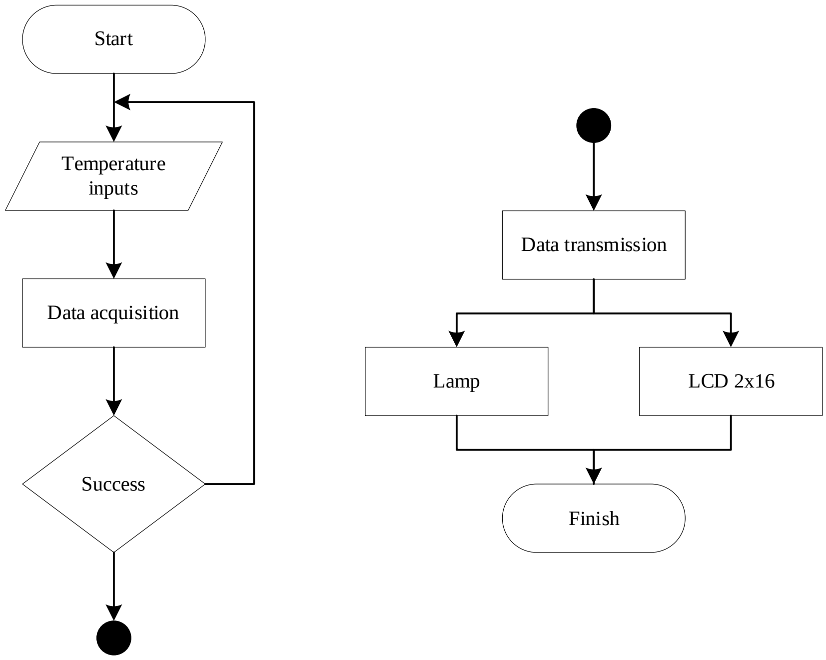

Figure 3. Flowchart of the tool's working system

2.3. Needs identification

The identification of needs is intended to determine what is needed at this stage of research. Tool design includes hardware design and the program used. Hardware design or it can also be called hardware is divided into 2 stages, namely mechanical design and electronic design. The design of the clothes dryer design with temperature control has 3 types of designs, namely mechanical design, electronic design and program design which will be explained in Figure 4.

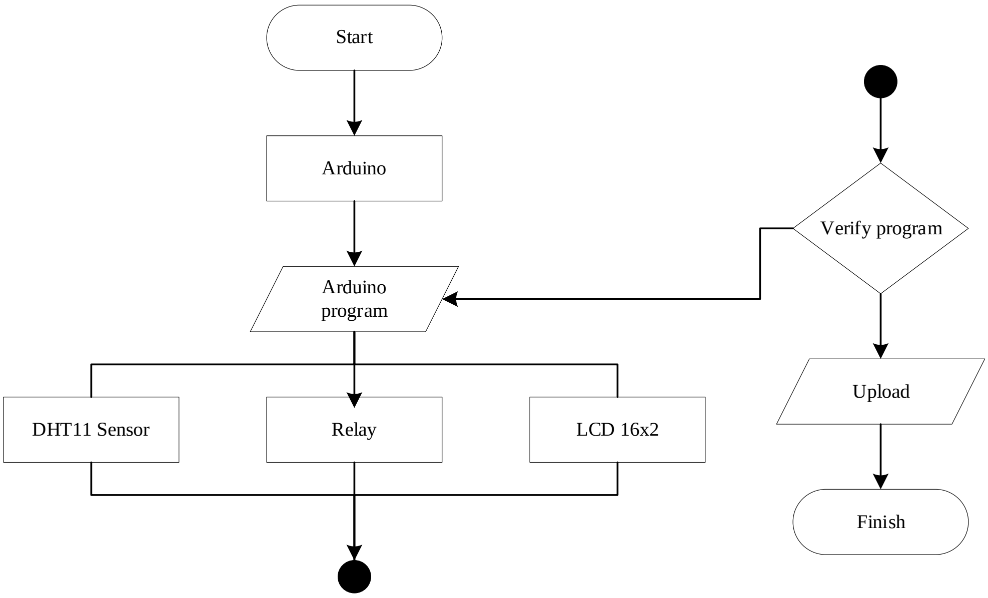

Figure 4. Program flowcharts

3. RESULTS AND DISCUSSION

3.1. DHT 11 sensor testing results

This test is to collect data and readings from the DHT11 sensor. The test results are in the form of temperature and humidity values. So that the output of this sensor is in the form of values. The following tools are required for the test, including.

a. Personal computer/laptop computer.
b. Arduino and others.
c. USB cable.
d. Arduino IDE programming
e. 3 experimental materials.
f. DHT11 sensor with a tolerance of ±2 °C for temperature and ±5% for humidity.

Here are the steps to test the DHT11 sensor, as follows:

a. Combine the Arduino and DHT11 sensors using jumper cables that address VCC, data ground to get data, connect to address A0 on the Arduino.
b. Turn on the PC/laptop.
c. Connect the computer/laptop to the Arduino Uno with a USB cable. Open Arduino IDE Programming on PC/laptop. C program controller in Arduino IDE. Here is an example of a program in the Arduino IDE:

```
#include <dht.h>
dht DHT;
#define DHT11_PIN A0
Void setup();
{
Serial.begin (115200) ;
}
void loop();
{
// Read the data
Serial.print ("DHT11، \t") ;
DHT.read11 (DHT11_PIN) ,
Serial.print(DHT.humidity, 1) ;
Serial.print ("، \ t");
Serial.println (DHT.temperature, 1) ;
delay (2000);
}
```

d. Once done, click the icon to confirm inside the Toolbar, if there are no syntax errors, upload to the generated program. When finished, press the “Serial Monitor” icon.
e. The serial monitor window will display the results of the program that has been run.
f. Observe the temperature and humidity results read by the sensor displayed on the serial monitor window.

In this test, data is taken from the DHT11 sensor. Data taken in the form of temperature and humidity where temperature has Celsius units while humidity contains relative humidity units. Data collection uses a humidity set point of 60 HR, if the humidity set point is reached, the system will automatically shut down. Idle is the system will turn off the fire source, namely the gas stove. Table 1 shows the test results.

Table 1. Comparison of DHT11 sensor results with thermometer

Time (minutes)	Tools Experiment I Temperature	Thermometer Experiment II Temperature	Difference	Deviation
1	34	33	33.5	0.5
2	36	35	35.5	0.5
3	38	39	38.5	0.5
4	40	42	41	1
5	42	41	41.5	0.5
6	44	44	44	0
7	46	45	45.5	0.5
8	48	47	47.5	0.5
9	50	50	50	0
10	52	52	52	0

The Table 1 then calculates the average error value of the DHT11 sensor reading with the formula:

$$Average = 4.5/10 = 0.45\%$$

So, the average error value of the DHT11 sensor reading is 0.45%. The LCD is tested by connecting the connected pins to the provided I2C, from I2C there are VCC, Ground, SDA, and SCL pins.

3.2. Drying test ignition process

The automatic drying test is carried out using the heat temperature of the heater. The way it works is that if the DHT11 sensor is indicated with 75% humidity, the heater will turn on with the help of a relay that will make the heater indicated alive. The test schedule can be seen in Table 2.

Table 2. Heater test results

Experiment I		Experiment II	
Seconds	Heater	Seconds	Heater
1	Off	1	Off
2	Off	2	Off
3	Off	3	On
4	On	4	On
5	On	5	On
6	On	6	On
7	On	7	On
8	On	8	On
9	On	9	On
10	On	10	On

3.3. Drying process comparison

The following data is obtained from the comparison of the drying process with solar heat and the jeans type clothes dryer used for the comparison experiment which is better. The testing process is carried out to find out which is better by using solar heat or by using a tool that has been made by researchers, carried out as many as eight trials or data collection at the same hour, can be seen in Table 3.

The difference in drying time and tumble drying time may be due to the unstable temperature of the sun and different jeans for each type of fabric absorbing heat in the drying process. Also, the cold wind coming out of the propeller is always blowing. One of the results is that the dryer dries faster than using the sun's heat. Humidity and fabric thickness also affect drying speed. The detailed results of the drying process can be seen in Table 4.

Table 3. Heat comparison

Solar heat			Drying equipment	
Experiment	Time (minutes)	Temperature (C)	Experiment	Time (Minutes)
1	240	37	1	80
2	242	38	2	82
3	245	38	3	85
4	243	38	4	84
5	241	38	5	85
6	240	35	6	85
7	242	36	7	80
8	240	37	8	83
Average	242	37.125	Average	82

Table 4. Drying process

Time	Experiment I		Experiment II		Average	
	Humidity	Temperature	Humidity	Temperature	Humidity	Temperature
1	93	35	92	35	93	35
2	92	36	92	36	92	36
3	90	37	90	37	90	37
4	88	38	88	38	88	38
5	86	39	86	39	86	39
6	83	40	82	40	83	40
7	80	41	80	41	80	41
8	78	41	78	41	78	41
9	75	42	75	42	75	42
10	72	42	72	42	72	42
11	69	42	69	42	69	42
12	64	43	66	43	66	43
13	63	44	63	44	63	44
14	59	44	59	44	59	44
15	56	45	56	45	56	45
16	53	45	53	45	53	45
17	49	45	50	45	50	45
18	48	46	48	46	48	46
19	45	47	45	47	45	47
20	41	47	41	47	41	47

From the data in Table 4, the temperature data of the clothes after giving wet clothes is 35 °C and the humidity of the clothes is 93 HR. The increase in temperature per minute averages 1 degree Celsius while the decrease in humidity per minute averages 1 HR.

3.4. Testing on a clothes dryer with three types of jeans

Testing the clothes dryer with three types of jeans can be done to test the performance of the clothes dryer on different types of jeans fabric. This is important to ensure that the clothes dryer can provide optimal results for all types of jeans fabric so that users can get satisfactory results and the jeans fabric is not damaged or over-dried.

The test steps on the clothes drying machine with three types of jeans are as follows:

a. Preparation of test materials
   Prepare three different types of jeans fabric, namely thick, medium, and thin jeans fabric. Then, cut the jeans fabric into the same size, for example, 30×30 cm.
b. Drying process
   Put the jeans fabric pieces into the clothes dryer, and set the temperature and drying time according to the instructions. Make sure all pieces of jeans are dried at the same temperature and time.
c. Measurement
   After the drying process is complete, take the jeans' fabric pieces and measure their weight with a digital scale. Record the weight of each piece of jeans fabric.
d. Analysis of results
   Based on the measurement results, analyze to determine if there is a significant difference between the different types of jeans fabric in terms of weight and dryness. The results of the analysis can be used to determine whether the clothes dryer can provide optimal results for all the different types of jeans fabric.

By testing the clothes dryer with three types of jeans, we can know how the clothes dryer performs on different types of jeans fabric. This can help users to choose the type of jeans fabric that is suitable for processing with a clothes dryer, as well as ensure that the drying results can be satisfactory and the jeans fabric is not damaged or over-dried by the machine.

3.4.1. Pants test

Testing of pants carried out under the condition that the machine enters when stepped on at the 4th minute. The machine is active but the clothes are not wet for 3 minutes. The results can be seen in Table 5.

Table 5. Pants test

Time	Experiment I		Experiment II		Average	
	Humidity	Temperature	Humidity	Temperature	Humidity	Temperature
1	82	33	80	33	81	33
2	82	33	81	33	82	33
3	82	35	82	35	82	35
4	93	36	92	36	92	36
5	92	37	91	37	91	37
6	88	38	89	38	89	38
7	86	39	86	39	86	39
8	83	40	83	40	83	40
9	80	41	80	41	80	41
10	77	41	78	41	78	41
11	75	42	75	42	75	42
12	72	42	72	42	72	42
13	70	42	69	42	69	42
14	66	43	66	43	66	43
15	63	44	63	44	63	44
16	58	44	59	44	59	44
17	56	45	56	45	56	45
18	53	45	53	45	53	45
19	50	45	50	45	50	45
20	49	46	48	46	48	46

The results in Table 5 show that at minute 3 the humidity graph increases until it reaches 93 HR and the temperature continues to increase. At the fourth to twentieth minute, the humidity data drops significantly, and the temperature on the temperature graph continues to increase.

3.4.2. Denim pants test

Testing on pants was carried out under conditions that have been set on the machine when it reaches 4 minutes, the machine is active but has not been given wet clothes for 3 minutes. The results can be seen in Table 6.

Table 6. Denim pants test

Time	Experiment I		Experiment II		Average	
	Humidity	Temperature	Humidity	Temperature	Humidity	Temperature
1	82	33	80	33	81	33
2	82	33	81	33	82	33
3	82	35	82	35	82	35
4	94	36	92	36	93	36
5	92	37	91	37	91	37
6	88	38	89	38	89	38
7	86	39	86	39	86	39
8	83	40	83	40	83	40
9	80	41	80	41	80	41
10	77	41	78	41	78	41
11	75	42	75	42	75	42
12	72	42	72	42	72	42
13	70	42	69	42	69	42
14	66	43	66	43	66	43
15	63	44	63	44	63	44
16	58	44	59	44	59	44
17	56	45	56	45	56	45
18	53	45	53	45	53	45
19	50	45	50	45	50	45
20	49	46	48	46	48	46

The results in Table 6 show that in the fourth minute, the humidity graph rises to 93 HR and the temperature continues to rise. At the fourth to twenty-fifth minute, the humidity data drops significantly, and the temperature on the temperature graph continues to increase. From the 15th minute to the 20th minute, the humidity graph decreased by 20 minutes. In 20 minutes this device only consumes an average of 64.8 Wh (0.065 kWh) of electricity, while one of the conventional dryers in the field with innovative low-power technology uses power in the range of 200 Wh (0.2 kWh) [26].

4. CONCLUSION

Based on the results of the system design and all tests conducted for various conditions in the jeans clothes dryer, several conclusions can be drawn. In the initial experiment, pants with an average humidity of 81% and a temperature of 33 °C were processed with the dryer. After 20 minutes, the humidity decreased to 48%, and the temperature increased to 46 °C. A similar outcome was observed in the denim pants experiment, which yielded consistent values. Furthermore, the drying process using the dryer proved to be faster than manual drying in the sun, so the objective of this research was achieved. The dryer reduces drying time by up to 67% (from 240 minutes to 80 minutes). The target humidity level, or set point, for the drying process was set at 20 HR relative humidity. For further research development to use more automation systems and the application of 100% green energy.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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Muthmainnah		✓		✓	✓		✓		✓		✓			
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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

INFORMED CONSENT

Informed consent was not applicable to this study as it did not involve human participants.

ETHICAL APPROVAL

This study did not require ethical approval because it did not involve experiments on humans or animals.

DATA AVAILABILITY

Data availability is not applicable to this study as no new data were created or analyzed.

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