MISTMATIC: Automatic Misting Control System for Indoor Garden with Rule-Based Approach

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ABSTRACT

Today, indoor gardening provides a stable food supply in end consumers, restaurants, and retailers. Extreme heat affects stress to the plants that can lead to exhaustion. Research says that plants are said to be on optimal condition if the temperature only ranges between 15-34 degrees Celsius. Anything higher than the said temperature will cause plants to suffer, deteriorate, and also affect the plants' productivity. The researchers successfully developed an automatic mist machine that is capable of cooling a surrounding area that can control the rise of temperature in protecting and maintaining the optimal temperature required for indoor plants in a garden with a Rule-Based method. The results of the two trials were all the same when it comes to temperature and humidity over time. The rise of temperature was the decrease in humidity and vice versa, making it inversely proportional to each other. However, it resulted that the higher the height of placement of the prototype, the longer it takes to cool down the surrounding area. The study shows that the testing of functionality and validation of the system resulted in a 100% success rate. The study verifies and proves that the system is effective and efficient in the issue of the temperature control system.

Key words : Arduino, Indoor Garden, Misting, Rule-Based, and Temperature Control,

1. INTRODUCTION

The Philippines is devastated and ruin by up to 10 tropical storms in a year and storms can destroy crops and interrupt food supply. So, Indoor farming is used to grow the plant inside the house and protect the crop from a natural disaster [1]. Today, indoor farming provides a stable food supply in end consumers, restaurants, and retailers. The application of modern ideas for indoor farming uses Controlled Environment Agriculture (CEA) technology where the technology controls the temperature, humidity, soil moisture [2], [3], and light that makes the production of crops indoor

possible. Gathered temperature can directly control the productivity of the plants [4]. Too high and too low-temperature supply to the plant can spoil the biochemical process and can cause an end to the plant growth.

The temperature can limit the growth of the plant and probably within the corresponding wide-ranging temperature restrictions [5]. The growth of the plant has three basic temperature points: first is the minimal temperature, the meaning is adequate for the plant growth to begin; second is the optimal temperature, the most beneficial for the plant growth; and the maximum temperature, at this point the plant growth ends. But some plant growth varies depending on the development stage, temperature adaptation, time of day, and the season.

Nowadays, due to global warming, the increase in temperature is causing a huge problem the world faces every day. The average global temperature has increased by about 1.4 degrees Fahrenheit (0.8 degrees Celsius) over the past 100 years, according to the National Oceanic and Atmospheric Administration (NOAA). This leads to experiencing extreme heat that can have a major effect on living organisms all over the world.

Extreme heat affects stress to the plants that can lead them to exhaustion. Research says that plants are said to be on optimal condition if the temperature only ranges between 15-34 degrees Celsius. Anything higher than the said temperature will cause plants to suffer and deteriorate. The extreme temperature will also affect the plants' productivity. So, watering the plant is important in gardening for controlling the amount of water and temperature [6]. In irrigation, an automatic watering system was used for their plants [7] but sometimes the amount of water going to the plants is too much.

The goal of the study is to develop an automatic misting system that controls the temperature of the surrounding of the indoor garden. Specifically, this study aims to assess the

effectiveness of the automatic mist machine involving cooling in terms of the time it will take for the temperature in the surrounding area to reach the optimal temperature required which is 34 degrees Celsius and to determine the lowest possible temperature achieved by the product in cooling the surrounding area. The study will benefit the garden owner because it will automatically water the plant through the use of a water misting system.

Misting system is used for fire extinguishing systems [8], controlling dust in the industrial warehouse [9], [10], and watering in the garden to create moist and humid surroundings. Usually, apply in hot weather to keep it cool and for tropical plants. Misting is widely known in agriculture application and sometimes misting nozzle is called foggers.

Gardening is one of the most preferable hobbies for most of people. There is one study prove an effective way of gardening through the use of "Smart Gardening", which converts all manual labor to an automatic system for watering and giving light to the plants [11]. The system also has an intruder detection camera to detect the intruders. Another smart watering system used in gardening with measuring the soil content and control the rate of flow of water to a sprinkler [12]. The system was controlled by a microcontroller Arduino and the goal of the study is to save water in gardening.

There is one study that was able to develop a system that can do the watering, fog the environment, and at the same time drain hydroponic nutrients automatically the garden [13]. Using the Internet of Things (IoT) and hydroponics to grow plants without soil is an example study that can be used in indoor gardening. The system was controlled by microcontrollers and sensors to keep the intervention of the owner of the garden at a minimum [14].

2. METHODOLOGY
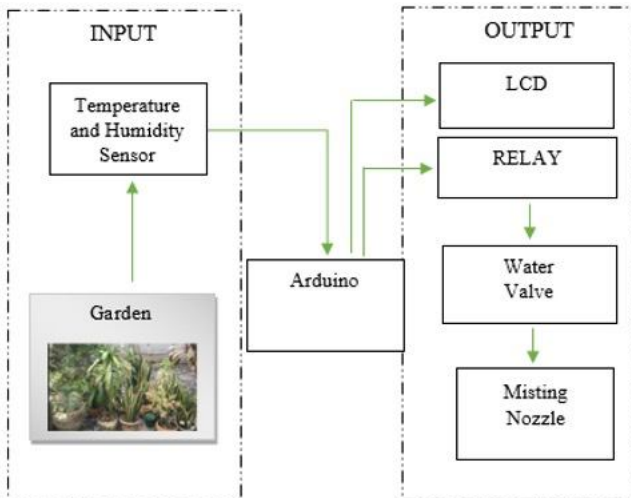
2.1 System Architecture

Figure 1: MISMATIC System Architecture

Figure 1 shows the connection of the devices and form as Automatic Mist System that is a temperature-dependent cooling device that can cool its surrounding area by using Arduino Uno. The Arduino Uno was programmed with rules of codes called Rule-Based, which will control the input and output devices. Misting produces mist rather than cool air. Temperature and Humidity Sensor (DHT11) are used as an input device to detect the garden surrounding readings. The study includes Water Solenoid Valve, Water Pipe, Piping Accessories, and 16x2 LCD as output devices. LCD device shows the values being read by the temperature sensor. All the materials have been used to make the Automatic Mist Machine.

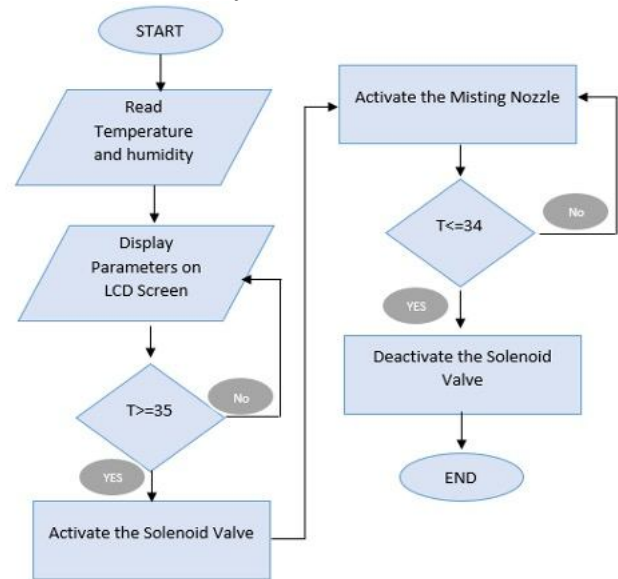### 2.2 Flowchart of the System

Figure 2: MISMATIC Flowchart

The system was designed with a supply 12 volts DC to the solenoid valve, 5 volts DC to Arduino, and plugged-in the water hose on the lower right side of the prototype. Figure 2 shows the flowchart of the automatic misting machine and begins by reading the temperature and humidity of the plants' surrounding using the DHT11 sensor. The LCD will then display the values of these two parameters read by the sensor. Once the temperature value reaches the threshold, which is any number greater than or equal to 35 degrees, it will stimulate the solenoid valve to open. Simultaneously, the misting nozzle will also be stimulated and will begin the misting of the surroundings. Due to this mist, the atmosphere will be regulated, and the appropriate temperature for the plants will be provided. If the temperature then decreased to any number less than or equal to 34 degrees, the system will close the valve, dismissing the flow of the water to the nozzles which will disable the misting. The process continues until the ideal temperature of the household plants' surroundings is regulated.

2.3 Schematic Diagram of the System

Figure 3 shows the connection of the whole system devices to the microcontroller. At pin A4 and A5 of the Arduino Uno, the LCD 12x2 is connected which shows the output reading of the DHT11 Temperature and Humidity sensor which on the other hand is connected at pin 7. Moreover, the 12V Electric Water Solenoid Valve is seen at digital pin 10 of the Arduino through a relay circuit. The water solenoid is a normally closed valve which means that whenever 12 volts are being fed to it, the valve will open. The water source is connected to the inlet of the valve where it allows water to flow. Furthermore, 2 misting nozzles are connected to the outlet of the valve which is placed and assembled along PVC pipes.
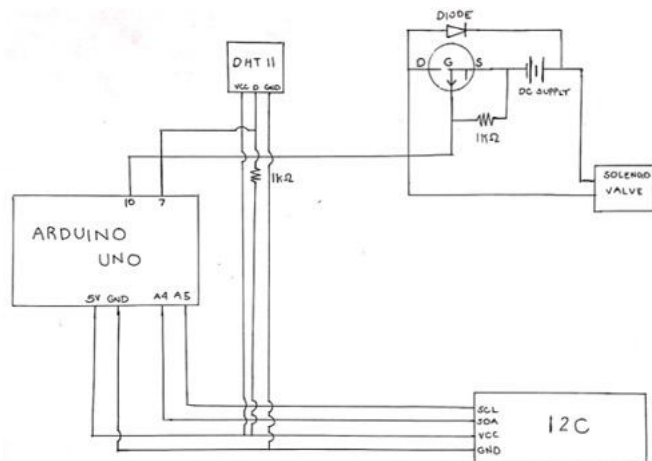

Figure 3: MISMATIC Schematic Diagram

2.4 Materials and Components

To develop the MISTMATIC: Automatic Misting System through Controlled Temperature Measurement with Rule-Based Approach, the following materials were applied to the proposed system:

A. *Arduino UNO*

Arduino Uno was a microcontroller where the program was stored and the brain of the whole system [15]. Arduino controlled the input and output devices as well as the processing condition of the program [16], [17].

B. *Liquid Crystal Display (LCD)*

Liquid Crystal Display (LCD) is the device used to output the readings of the sensor [18].

C. *Relay and Water Solenoid*

Arduino Relay and Water Solenoid valves are used for simple on/off control of the water flow.

D. *Misting Nozzle*

Misting Nozzle used to spray mist for a cooling system of the indoor garden. This component will produce mist to change the temperature of the environment and water the plants.

2.5 Rule-Based

The Rule-Base is storage of rules and each rule is designed by the "IF-THEN" statement [19]. A knowledge illustration type used in Artificial Intelligence called a rule base. The IF part is the conditional specified information and the THEN part is the action of the system. To respond to a problem, a rule offers some descriptions and the following rule that are used in the system:

1) *if (Readings are detected) then (Display the readings to the LCD)*
2) *if (temperature is greater than or equal 35°C) and (humidity is HIGH) then (Activate the solenoid valve)*
3) *if (temperature is less than or equal 34°C) and (humidity is NORMAL) then (Deactivate the solenoid valve)*

2.6 Hardware Prototype of the MISMATIC

Figure 4 shows the prototype of the Automatic Misting System. The two brass that can be seen in the photo is the misting nozzles that provide fine drops of water. It is where the cooling of the surrounding process takes place. The plants present in this application were Snake plant, Fern, Fortune plant, Aloe Vera, Palm plant, and Spider plant. Their productivity was based on temperature and moisture of the soil which was monitored using the DHT11 sensor which was placed at the side of the first nozzle to the right, connected into circuitry and Arduino Uno. Any value of temperature higher than 34 degrees can have bad effects or worse dry the plants. The location of the DHT11 sensor is in between the two misting nozzles.

Figure 4: Indoor Garden and the Prototype

Figure 5 shows the components placing inside the prototype and the following are the labels in the image: 1) Arduino Uno; 2) Cable Connector; 3) LCD Screen; 4) PCB Circuit; 5) Metal Coupling; 6) Solid Wires; 7) 12volts Solenoid Valve; 8) PCV Pipes; 9) Hose Connector; 10) Direct Hose, and 11) Plywood Casing.
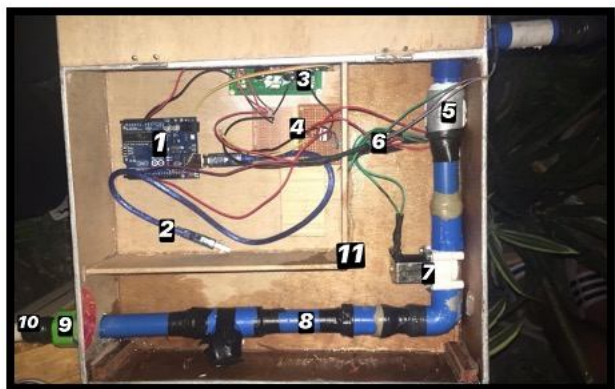
Figure 5: Inside Part of the Prototype

3. RESULT AND DISCUSSION

3.1 Functionality Testing

Functionality testing for the Automatic Misting System was done by the researchers to check if the hardware components and software performs as expected. Table 1 shows the software and hardware components testing.

Table 1: Testing of the components

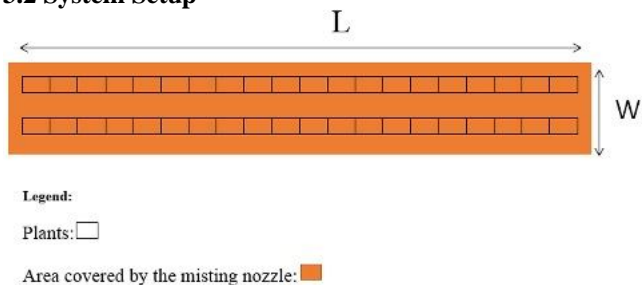| No.	Testing Activities
1	The sensor will measure the temperature and humidity level.
2	The LCD will output the readings of the sensor
3	The Misting Nozzle will be activated and produce mist
4	The Misting Nozzle will be deactivated

3.2 System Setup

Figure 6: Wide Range Area of the Misting Nozzle

The researchers compute first the misting nozzle range in the garden. Equation 1 shows the computational formula to accumulate the area range of the two-misting nozzle. The researchers set two (2) trials with different height of nozzle. Figure 6 shows the area computation of the garden range of the misting nozzle.

$$Area = Length \times Width \tag{1}$$

TRIAL 1: Height of misting nozzle = 1 m
AREA = 2.1336 m x 1.2192 m
AREA = 2.6013 sq. meters

TRIAL 2: Height of misting nozzle = 1.143 m
AREA = 2.5908 m x 1.3716 m
AREA = 3.5535 sq. meters

The computations consist of the height, length, width, and the total area that can be covered by the misting. In trial 1, the researchers placed the device with a height of 1 m having 2.6013 m^2 area covered. In trial 2, with a height of 1.143 m, the area covered was 3.5535 m^2; which proves that the higher the height where you placed the misting device, the larger area it covers.

3.3 Testing and Result

Testing is done with two (2) trials and Table 2 shows the result of the first trial. When the device was turned on, initially the temperature and humidity reading was 33 °C and 58% respectively.

Table 2: Results of Trial 1

Time(seconds)	Temperature (°C)	Humidity (%)
0	33	58
1	33	58
2	33	58
4	33	58
6	33	58
8	34	58
10	34	57
12	34	57
14	35	57
16	35	57
18	35	50
20	36	50
22	37	50
24	37	50
26	37	50
36	37	49
48	36	49
52	36	48
64	35	48
78	35	49
80	34	50
82	33	54
83	33	58

Slowly the temperature increases and at 10 seconds, the temperature and humidity reading were 34 C and 57%. As the temperature continuously increases, at 14 seconds, you can see that the readings were 35 °C and 57% humidity, which was the starting point that it will trigger and start misting (solenoid valve is now open). At 36 seconds having the maximum temperature reading 37 °C and 49% humidity. As the misting continues and is still on, the temperature slowly decreases and the humidity finally increases. At 80 seconds, the reading was 34 °C temperature and 50% humidity, which will be the time when the circuitry will be disabled and the solenoid valve. In this trial, testing able to have the lowest temperature result of 33 °C and 58% as the highest value of humidity, where values returned to the initial reading by the DHT11 sensor.

Table 3: Results of Trial 2

Time(second)	Temperature (°C)	Humidity (%)
0	33	56
2	33	56
4	33	56
10	33	56
12	34	57
14	34	57
30	34	56
36	34	55
44	34	54
64	34	54
74	35	51
84	35	50
94	35	50
120	35	50
152	36	51
158	36	51
162	35	53
170	34	53
176	33	53
180	33	53

Table 3 shows the results of the second trial. Initially, the temperature and humidity readings were 33 °C and 56% respectively at 0 seconds. The temperature increases at 12 seconds, the readings were 34 °C temperature and 57% humidity. As the temperature again continuously increases at 74 seconds, the readings were 35°C temperature and 51% humidity, again reaching the threshold will trigger and start misting (solenoid valve is now open). At 58 seconds the system getting the maximum temperature reading at this trial having 36°C and 51% humidity. As the misting continues and is still on, the temperature slowly decreases and the humidity again increases. At 170 seconds, the reading was 34°C temperature and 53% humidity, which will be the time when the circuitry will be disabled and the solenoid valve will be closed. In the second trial, the researchers were able to have the lowest temperature result of 33°C and 53% as the highest value of humidity.
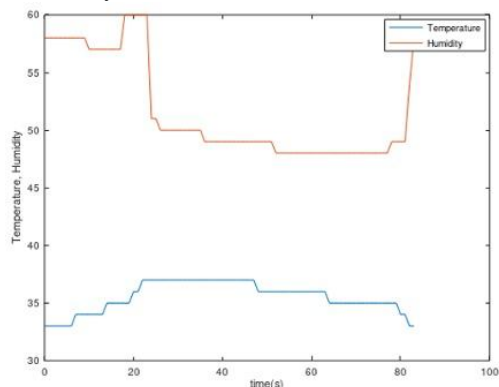

Figure 7: Trial 1 Graph of Temperature and Humidity over Time

In figure 7 shows the graph with plotted values of the data gathered in Table 2. The graph still shows that the rise of the temperature is the decrease in the values in humidity. The highest temperature was attained from 22 seconds to 47 seconds is 37°C. The lowest humidity was at 48% for 50 seconds to 78 seconds.
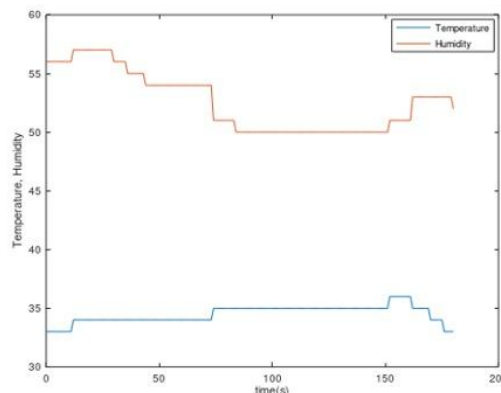

Figure 8: Trial 2 Graph of Temperature and Humidity over Time

In figure 8 shows the graph with the plotted values of the data gathered in Table 3. The graph again proves that the increase of the temperature is the decrease in humidity. In this graph, the highest temperature was attained from 152 seconds to 158 seconds is 36°C and the lowest humidity was at 50% from 84 seconds to 120 seconds.

4. CONCLUSION

The researchers successfully developed an automatic mist machine that is capable of cooling a surrounding area that can control the rise of temperature in protecting and maintaining the optimal temperature required for indoor plants in a garden. The lowest temperature that the system can get resulted only to 33 degrees Celsius but perfectly fall on the range that the plants were said to grow fruitfully. Due to these results, the researchers conclude that as the height of placement increases, the area it covers become larger. The results of the two trials were all the same when it comes to temperature and humidity over time. The rise of temperature was the decrease in humidity and vice versa, making it inversely proportional to each other. However, it resulted that the higher the height of placement of the prototype, the longer it takes to cool down the surrounding area. The study shows that the testing of functionality and validation of the system resulted in a 100% success rate. The study verifies and proves that the system is effective and efficient in the issue of the temperature control system. The researchers would like to recommend to create a more stable stand and more suitable casing for the prototype. The researchers experienced difficulties in making a device perfectly without leak that is why we fully recommend future researchers to use Pipe cement and more Teflon tapes on the PVC pipes to avoid leakage. Adding a network sensor, monitoring through cloud or IoT, and deep learning approach is recommended by the study to make improvements to the system.

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