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Smart Plant Pot Robot with IoT Integration for Indoor Ornamental Plants Care

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A B S T R A C T

Caring for indoor ornamental plants is a challenge for the owner. They require special attention and treatment from the owner to grow well and beautifully. The most important and common thing that must be considered is choosing the type of plant that can adjust to the atmosphere and conditions in the room. Some indicators that determine the typical environmental conditions of potted ornamental plants are air temperature and humidity, light, and soil moisture. The smart plant pot robot is designed to provide smart care for indoor ornamental plants by incorporating a line follower mechanism. Equipped with functionalities like plant watering and environmental monitoring (including light, temperature, and humidity levels), this robot offers comprehensive plant care. Users can conveniently monitor these parameters via a smartphone using the Blynk application. In its design, the robot integrates various components such as temperature and humidity sensors, light intensity sensors, photodiode sensors, ultrasonic sensors, voltage sensors, Arduino Uno, relays, water pumps, RTC, ESP8266, DC motors, and motor drivers. The primary goal is to create a system capable of monitoring plant conditions and providing watering assistance, utilizing line tracking for transporting potted plants to sunlight exposure spots. This system aims to offer practical benefits to the community, especially in optimizing indoor ornamental plant care. The test results of this system, utilizing Arduino Uno as the microcontroller and ESP8266 for WiFi communication with the Blynk application, along with various sensors as input devices, demonstrate a remarkable 100% success rate. Notably, this accuracy is based on functional testing, encompassing everything from the robot's path detection to its connectivity with the Blynk application.

INTRODUCTION

Ornamental plants are a type of plant that has more aesthetic value than other plants, so many people deliberately maintain and breed them for purposes such as decorating the room and beautifying the yard. Taking care of your own ornamental plants is certainly a lot of fun. According to data from the Central Bureau of Statistics, interest in ornamental plants (floriculture) in 2019 increased by 6.1% compared to the previous year [1]. In Indonesia itself, many people have a hobby of collecting indoor ornamental plants, especially used as decorations to beautify the room in the house. One of the indoor plants that is in great demand is the D. Marginata Tricolour plant.

*Dracaena marginata T*ricolor, well known as Tricolor, is a beautiful *indoor* ornamental plant with a long leaf shape but is not wide like a pipe, is slender and dark green, the edges are red with a small quantity of green touch, and is white[2] . Factors that affect growth in tricolor plants are the frequency and volume of watering, light, temperature, and humidity. Indoor ornamental plants require light intensity of 300-400 *footcandles.* The recommended relative humidity for *indoor* ornamental plants to grow well ranges from 30-50%, and the ideal average temperature for *indoor* ornamental plants is 21-320C.

Caring for indoor ornamental plants is a challenge for the owner. They require special attention and treatment from the owner to grow well and beautifully[3]. The most important and common thing that must be considered is choosing the type of plant that can adjust to the atmosphere and conditions in the room. Some indicators that can determine the typical environmental conditions of potted ornamental plants are air temperature and humidity, light, and soil moisture [4].

Efficient monitoring can be achieved by implementing innovative methods that enable ornamental plant owners to remotely access real-time data on the condition of their plants without manual intervention. Using sensors embedded in the plant pots, measurement data is transmitted to a microcontroller and then stored on a cloud-based server via the Internet. This approach facilitates automated and remote watering of ornamental plants, enhancing efficiency and ease of maintenance. The underlying concept employed in this study is known as the Smart Plant Pot.

Previous studies have demonstrated the successful development of applications for monitoring conditions, plant humidity, and plant watering through smartphone integration [5]. Additionally,

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another study introduced a smart pot system utilizing IoT technology to monitor ornamental plants efficiently, providing real-time environmental updates accessible via smartphones and linked to social media platforms like Twitter[4]. Furthermore, a research focused on robot implementation for watering vegetable, fruit, and flower plants within a greenhouse system, utilizing a PID (Proportional, Integral, Derivative) control method. The robot is equipped with a Photodiode sensor for watering, path detection, and stopping, enabling it to activate the water pump autonomously to irrigate the plants[6].

This study aims to develop and evaluate a smart plant pot system incorporating a line follower robot for automated plant care, leveraging IoT technology. The research aims to design a user-friendly and efficient solution that integrates real-time plant monitoring, automated watering, and robotic assistance to enhance the overall plant care experience. By focusing on the design and implementation of this innovative system, the researchers seek to demonstrate the feasibility and potential benefits of utilizing robotics and IoT in plant care practices.

METHOD

The general design of the system shown in Figure 11, it includes all the components that will be used to design smart plant pots with the application of line follower robots as ornamental plant transportation.

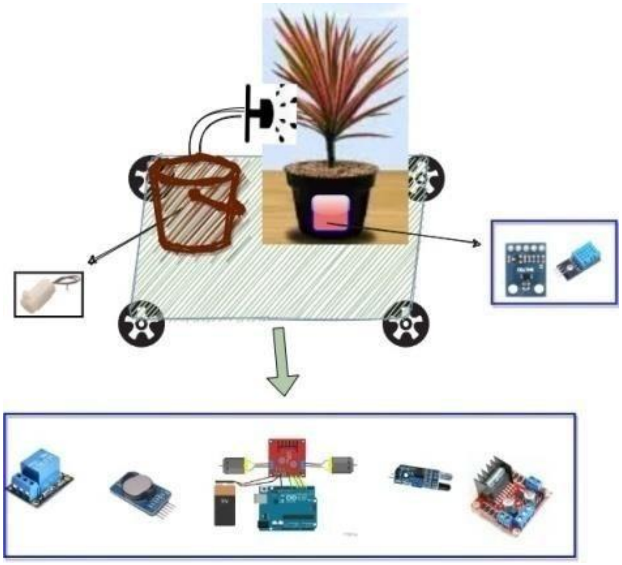
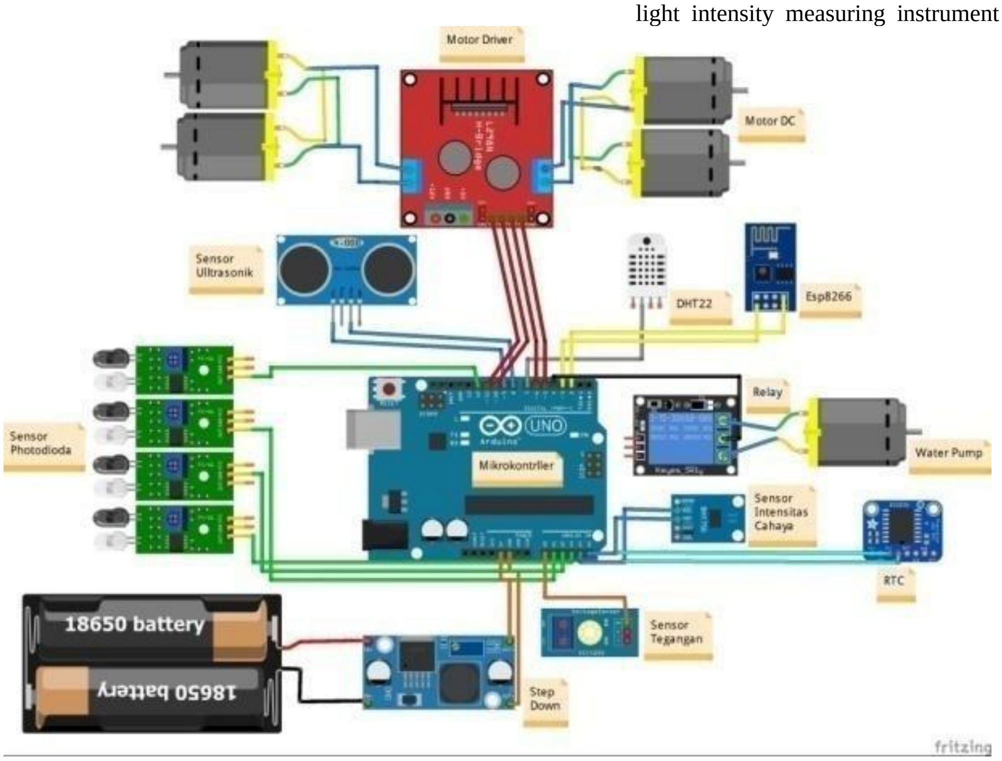


Figure 1. System Design

Based on the results of the data, this system is expected to provide information to plant owners through smartphone applications by utilizing the Blynk platform.

The system has some component consisting of:

a) BH1750 light sensor module: is a digital light sensor that has a digital signal output, so it can take measurements with lux (lx) output without the need to do calculations first [7]. The light intensity sensor is the most important part in this light intensity measuring instrument circuit. The sensor



used is a digital light intensity sensor module because this circuit is felt to be more accurate than other sensors such as photodiodes or LDRs. This sensor was also chosen because of its easier use because the output signal is already digital so there is no process calculation or processing in the microcontroller [7] .

b) DHT22 sensor; is a combined sensor that reads air temperature and humidity data relatively which produces a

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calibrated digital signal output. The advantage of the DHT22 sensor is that the measurement conversion is already digital and the calculation is done by an 8-bit MCU [14]. This sensor can measure temperature with a range of -40°C -125°C and humidity 0% - 100% and has a sampling rate of 0.5Hz, which means it reads temperature and humidity every 2 seconds[8].

c) Photodiode sensor: is a photo sensor as a line color detection. If more light is received by the photodiode from the LED, the diode resistance value will be minimum so that if the sensor is above the black line, the sensor Vout value will approach logic 0 (low), and vice versa [9].

d) HC-SR04 Ultrasonic Sensor: is a devices that convert sound waves into electrical signals and vice versa. The HC-SR04 ultrasonic sensor operates by emitting ultrasonic waves at a frequency of 40,000 Hz, which travel through the air. When these waves encounter objects or obstacles within their range, they bounce back to the sensor module[10].

e) RTC: is a device to monitor the date and time of each measurement accurately. This RTC synchronizes with the MCU via an inter-integrated circuit (I2C) bus, providing precise timing for data collection. Moreover, equipped with a dedicated battery, the RTC ensures continuous time tracking, even in situations where the data logger is inactive or without power[11].

f) Water pump; A pump is a device for moving liquid substances that flow from one place to another that works with mechanical energy given to increase speed, pressure or elevation (height). Water pump will move water from a low place to a higher place or to a higher elevation a farther place [12].

g) Relay as a switch for the water pump when watering plants. Relay is an electrically operated switch [6]. Relay serves to control the voltage as a relationship selector, delay circuit cultivator (delay), and current breaker under certain conditions.

h) Arduino Uno: is a microcontroller-based board on ATmega328. This Arduino Uno has 14 digital input/output pins (6 pins can be used as PWM outputs), 6 analog inputs, 16 MHz crystal oscillator, and USB connection and reset button power jack.

i) The ESP8266 WiFi module: is used to communicate between all systems with microcontrollers. ESP8266 is a wifi module that functions as an additional device for microcontrollers such as Arduino to connect directly to wifi and establish a TCP / IP connection[13].

j) DC motor: is a motor that uses direct voltage as its power source. DC motors are used to drive robot wheels. The motor will rotate in one direction when given a voltage difference on both terminals. If the polarity of the voltage is reversed, the direction of rotation of the motor will be reversed as well. The voltage used to rotate a DC motor is around 6V-12V or more[6].

k) Motor Drive, which is used to amplify the current entering the motor. In this research using IC type L293D. This L293D IC is an IC with a special design as a DC motor driver and can be controlled with a TTL circuit or microcontroller.

l) Battery: is a device containing electrical cells that can store energy and convert it into power.

m) Blynk: is an iOS and Android operating system platform to control Arduino, Raspberry Pi, ESP8266 and other similar devices via the internet

In Figure 13, the operational functionality of the smart plant pot is illustrated. Smart plant pots connected to WiFi can communicate with smartphones equipped with the Blynk application. Apart from presenting data, users can utilize the Blynk application to regulate the watering of plants in the smart plant pot either manually or automatically.

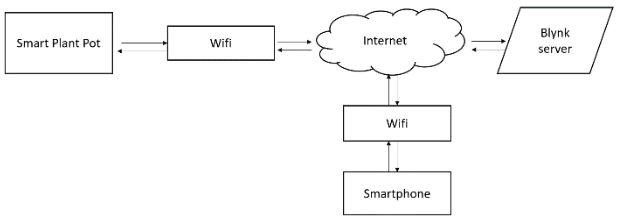


Figure 13.Diagram of How *Smart Plant Pot* Works

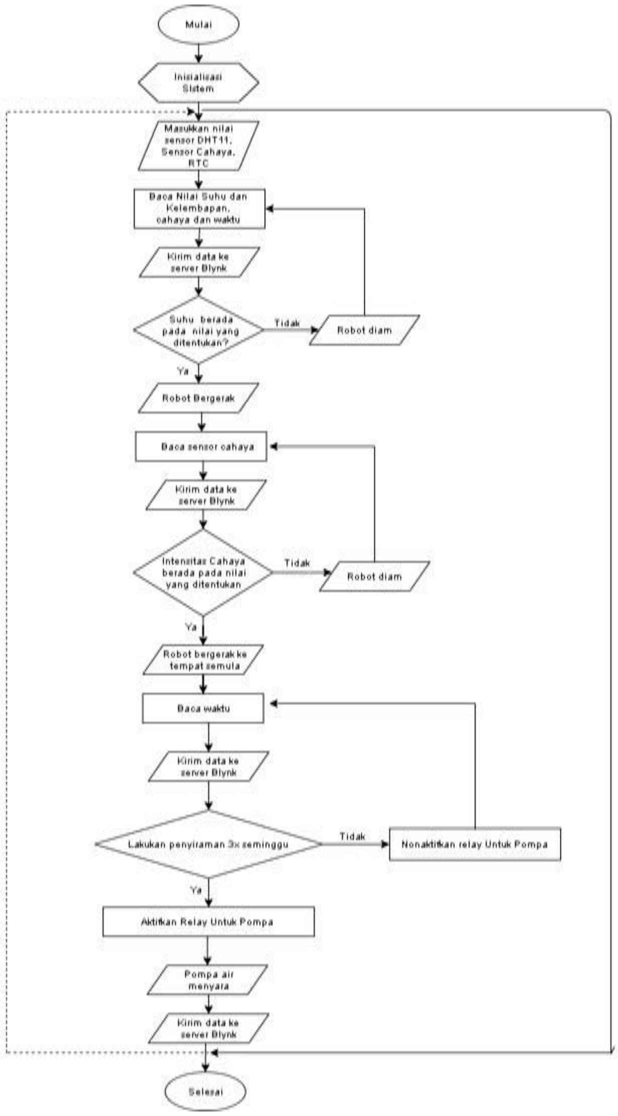


Figure 14 shows the flowchart of the overall design of the smart plant pot system. The start section indicates the initial stage of the program starting to work when the device is turned on. Next, the smart plant pot simultaneously detects light intensity, temperature, and humidity. When the DHT22 sensor exceeds the user-defined number, the program will activate the line follower robot to move according to the specified path. When the detection of light intensity reaches a specific value that the user has determined, this smart potted plant will return to its original place and be adjusted to the specified time while in direct sunlight. Based on the reading of the time range value that the user has determined, it will turn on the water pump to water the plant automatically and then send the data back to the Blynk server. The light intensity, temperature, and humidity readings use a different timer function than the water pump program, allowing the program to loop in parallel. The sensors will work in hours, while the water pump will work in weeks.

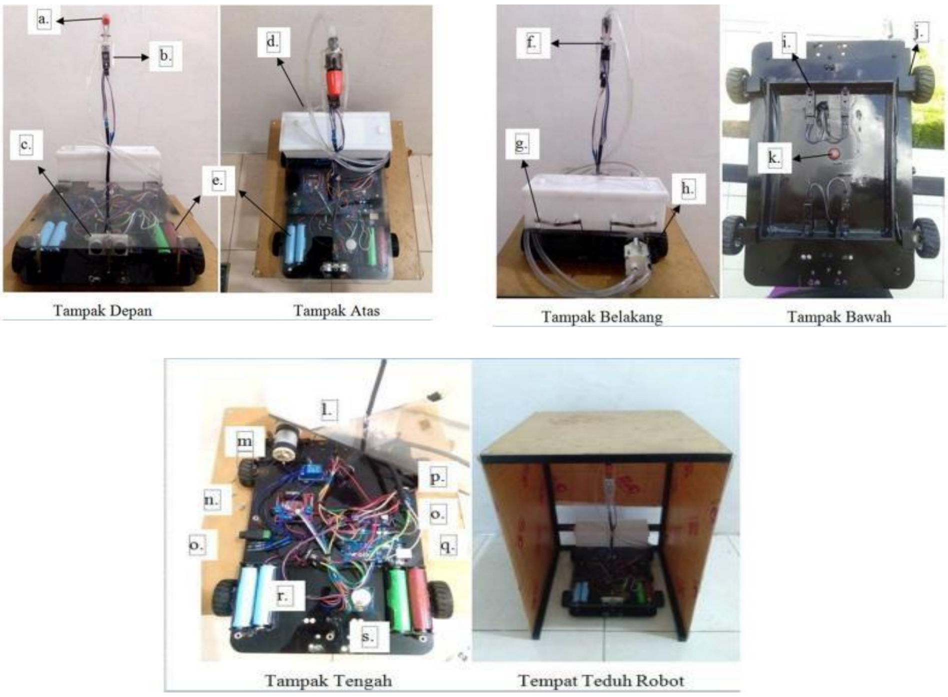
Blynk App Design

The Blynk application design features a gauge widget for showcasing sensor data and RTC-derived temperature, humidity, and time values. Additionally, it incorporates system controls like water pump on/off and system on/off functionalities. Moreover, including a notification widget enhances the user experience by providing alerts regarding the status of smart potted plants. This detailed design layout can be observed in Figure 15 of the article.

Figure 15. Blynk App Design

RESULT AND DISCUSSION

The hardware implementation outlines the development of a smart robotic plant pot that operates outdoors, positioned strategically between a shaded area and a well-lit area. The system allows the plant owner to define the trajectory for the robot to track the light source when the plant needs light autonomously. This setup is visually depicted in Figure 16 of the article.



Annotation:

a. Sprayer
b. DHT22 sensor
c. Ultrasonic Sensor
d. Water Container, Hose
e. Battery
f. BH1750 Sensor
g. Battery Steel Plate
h. Water Pump
i. Photodiode Sensor
j. DC motor
k. Push button
l. Relay
m. Driver motor
n. Adapter Socket
o. Step Down
p. Voltage Sensor
q. Arduino Uno
r. RTC
s. ESP8266

Figure 4.6 shows data obtained from implementing voltage sensors, BH1750 sensors, DHT22 sensors, and plant watering status on the Blynk application device. The Blynk application is an additional tool that enables remote monitoring of parameters such as battery voltage, light intensity, temperature, air humidity, and watering status. This integration of sensors with the Blynk application allows for convenient and remote tracking of vital metrics related to the smart robotic plant pot system Battery shows the number of batteries in voltage (V) and arbitrary units (%), Lux shows the value of light intensity in footcandles (fc), Temperature and Humidity show the air temperature reading in centigrade and relative air humidity in arbitrary units.

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Figure 19. Blynk App Implementation

System testing and analysis is executing hardware and software to determine whether the system framework meets the analysis needs. Testing is done to see the potential blunders from each execution process. In testing, the first step is to test the input devices, explicitly trying out measurements from sensors, including the DHT22 sensor, BH1750 sensor, ultrasonic sensor, photodiode sensor, RTC, water pump, and battery. Then, overall testing of the robot control system and plant monitoring that can be connected to the internet through the Blynk application was also carried out. Data was collected in an open space in Padang on 18 September 2021.

BH1750 Light Sensor Testing

This test aims to measure light intensity on plants by comparing the accuracy level of the BH1750 sensor reading with the light meter measuring instrument. The light meter used is a smartphone application. This application features ALS (Ambient Light Sensor), with light output proportional to light intensity, so this device is accurate enough to provide information on the size of the ambient light. The light meter uses an APDS-9922 light sensor, has an Avago vendor, resolution reaches 16, and the light intensity reading range reaches 30,000 lux. ‘

In Figure 20, displays the test results of the light intensity sensor displayed through the serial monitor. The image displays the results of the light intensity of 3.17 fc, which is placed in the room. Figure 20. BH1750 Sensor Testing Results on Serial Monitor: Table 1 is the test result of the BH1750 sensor on ornamental plants for ± 12 hours.

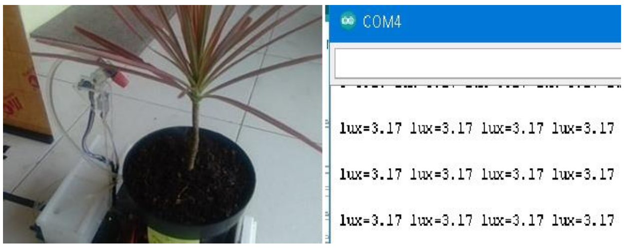

Figure 20. BH1750 Sensor Testing Results on Serial Monitor

Table 1. BH1750 Light Sensor Testing Results

BH1750 (fc)	*Light* Meter (fc)	Error (%)
6,43	6,1	5%
10,53	10,38	1%
18,35	18,98	3%
224,2	222,88	0,5%
376,56	375	0,4%
546,27	542	0,7%
32,36	32	1%
69,99	73	4%
72,85	73	0,2%
67,51	67	0,7%
6,04	6	0,6%
1,55	1,5	3%
Average *Error*:		1,675%

Table 1 illustrates that the BH1750 light sensor can measure the light intensity surrounding the plant with a minimal overall average error rate of 1.675%. The findings suggest that the sensor exhibits high accuracy in measuring light intensity.

DHT22 Sensor Testing

Testing the DHT22 sensor involves measuring temperature and humidity values, monitoring the sensor readings, and presenting them in the Blynk application. Subsequently, the sensor data will be juxtaposed with the measurements from a hygrometer to gauge air temperature and humidity. The hygrometer has a temperature measurement span of -100°C to 500°C and a humidity measurement range of 10% RH to 90%. Figure 21 depicts the Blynk display and the hygrometer showcasing the results of air temperature and humidity measurements.

Figure 21: Display of Air Temperature and Humidity Measurement from Blynk and Hygrometer

The results of the DHT22 sensor readings and hygrometer measurements from the test results that have been carried out for 12 hours in front of the house porch, can be seen in the Table 2. As indicated in Table 2, the average differential error of the DHT22 sensor is 1% for temperature and 7% for air humidity measurements. While the sensor's accuracy can be considered satisfactory, there remains a discrepancy between the DHT22 sensor readings and those of the Hygrometer device. Despite this variance, the sensor successfully captures temperature and humidity data despite the relatively minor deviations.

Table 2.Test Results Comparison of DHT22 Sensor and Hygrometer

Temperature DHT22 (^{0} C)	*Thermometer* (^{0} C)	*Error* (%)	*Humidity* DHT22 (%)	*Humidity* (%)	*Error* (%)
26,2	25,1	4%	74,5	66	11%
27,3	26,7	2%	73,4	66	10%
27,8	28	0,7%	72,4	66	8%
29,3	29,1	0,6%	71,6	64	10%
31,1	30,8	0,9%	68,2	63	7%
31,9	30,9	3%	66,2	62	6%
31,5	31	1%	63,8	61	4%
31,6	31,2	1%	64,9	61	6%
31,8	31,2	1%	64,1	59	7%
32	31,8	0,6%	61,3	58	5%
30,2	29,8	1%	70,4	63	10%
29,5	29,4	0,3%	72,7	64	11%
Average *Error Temperature:*		1%	Average *Error Humidity:*		7%

Ultrasonic sensor testing

Ultrasonic sensor testing aims to test the sensor response when given an obstacle in the form of an object. The ultrasonic will measure the distance of the object to the sensor and read the obstacle on the robot's trajectory.

Table 3.Ultrasonic Sensor Testing

Detected distance by HCSR-04 (cm)	Actual distance by ruler (cm)	Difference (cm)	Error (%)
2	2	0	0
4	4	0	0
6	6	0	0
8	9	1	12,5%
10	11	1	10%
Average error			4,5%

Based on Table 3, it can be seen that the ultrasonic sensor on the robot can read obstacles in the form of drinking bottles on the front of the robot. According to the programming in Arduino ide, the highest ultrasonic sensor reading is 10 cm. The measurement value has an error, or the comparison value measured by the sensor and the ruler is pretty close.

Photodiode sensor testing

Photodiode sensor testing is done to see the accuracy response given by the *photodiode* sensor in recognizing dark or white lines. *Photodiode* sensor testing is done by placing the robot in a certain position and then bringing the *photodiode* sensor closer to the robot at a certain height distance from the dark or white colored lines placed on a path. In testing this *photodiode* sensor, several variations in the width of the black robot path were carried out to see the accuracy of the sensor.

From Table 4, it can be seen that the photodiode sensor can measure the presence of color at a certain distance. The photodiode sensor can detect colors with a distance of 1-2 cm; above a distance of 2 cm, the photodiode sensor cannot detect anything

The results obtained from testing the photodiode sensor can be observed in Table 4 provided below.

Line width (cm)	Description
1	Unsuccessful
1.5	Successful
2	Successful
3	Successful
3.5	Unsuccessful

.RTC Testing

In this research, RTC (*Real Time Clock*) is used for real time reference with the time to be entered by the *user*. The time on the RTC is set equal to the current time RTC testing aims to see the ability to measure time with high accuracy and can determine when the robot operates and the plants will be watered. Seen in table 5, RTC testing to recognize the time and restrictions given based on the Arduino program.

Based on the test results from the table above, it is concluded that the test results of the time data set on the RTC are in accordance with real time and are declared capable of calculating time with 100% accuracy

ESP8266 WiFi Connection Testing

Figure 23 shows the successful testing of the ESP8266 connection with the Blynk platform, as monitored through the serial monitor of the Blynk programmer in the Arduino IDE. This setup enables WiFi communication between the ESP8266 module and the Blynk application on a smartphone. The serial monitor output displays crucial information, including the Indihome WiFi IP address (192.168.100.175), indicating readiness for data transmission to the Blynk app. In addition, evaluations were conducted to assess the WiFi signal strength received by the ESP8266, with tests conducted outdoors using a smartphone hotspot operating at 2462 MHz. The signal strength was measured in dBm units, with the smartphone network utilizing 4G technology and exhibiting -83 dBm signal strength and 53 ASU. ASU represents a scaled measure of signal strength from the nearest Base Transceiver Station

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Table 5. RTC testing

No	Test item	Successful/ Not Succesful	Description
1	Is the system able to recognize the operating time of the robot during period time	Successful	The robot will work and move for 12 hours, and will be idle outside of the time set by the plant owner.
2	Is the robot is able to do automatic watering 2x a day, namely in the morning at 8am and in the afternoon 5 o'clock today?	Successful	The robot will work and move for 12 hours, and will be idle outside of the time set by the plant owner The robot managed to water the plants for 2x a day both in t h e morning and in the afternoon according to the time that has been set, w a t e r i n g water is done for 1.5 seconds.
3	Is RTC is able to calculate the time when the plant is searching for sunlight and able to calculate the time accurately?	Successful	When plants need light and detect light <300fc then the calculation time will be done for 2 hours and the plant will stay in that place, the second requirement is if the detected light is 400-1,000fc then the calculation time of the plant is silent for 1 hour and if> 1,000fc then the time is still. counted for ½ hour.

Based on the findings presented in Table 6, it is determined that the smart pot robot system can establish a reliable connection with the WiFi hotspot within a distance range of 1 meter to 13 meters. The analysis of data transmission levels from the system to the Blynk application demonstrated a success rate of 93.33%. This success rate was influenced by both the distance between the devices and the quality of the smartphone hotspot network signal used for transmitting data processed by the microcontroller to the Blynk application. The signal strength ranged from -16 dBm to -82 dBm, indicating that a higher dBm value (in negative numbers) corresponds to a weaker signal.

Table 6. Testing WiFi Signal Strength

No.	Robot Distance to WiFi	Network Speed	*Latency*	Signal Strength	Description
1.	0 meters	72 Mbps	2 ms	-16 dBm	Data sent
2.	1 meter	72 Mbps	2 ms	-38 dBm	Data sent
3.	2 meters	72 Mbps	2 ms	-48 dBm	Data sent
4.	3 meters	72 Mbps	3 ms	-49 dBm	Data sent
5.	4 meters	72 Mbps	5 ms	-52 dBm	Data sent
6.	5 meters	72 Mbps	10 ms	-54 dBm	Data sent
7.	6 meters	57 Mbps	17 ms	-70 dBm	Data sent
8.	7 meters	57Mbps	21 ms	-71 dBm	Data sent
9.	8 meters	65 Mbps	28 ms	-72 dBm	Data sent
10.	9 meters	57 Mbps	32 ms	-73 dBm	Data sent
11.	10 meters	52 Mbps	60 ms	-79 dBm	Data sent
12.	11 meters	43 Mbps	74 ms	-80 dBm	Data sent
13.	12 meters	43 Mbps	75 m	-81 dBm	Data sent
14.	13 meters	12 Mbps	90 ms	-82 dBm	Data sent
15.	14 meters	12 Mbps	100 ms	-85 dBm	Data is not Sent

DC Motor Testing

DC motor testing is carried out by giving different loads to the to the robot wheel drive. The test was carried out by giving a load to the robot in a variation with a straight robot trajectory of 2.3 meters from the starting position to the position of the last point of the track. Here in Figure 24 testing the motor load on the robot of 1.5 Kg.

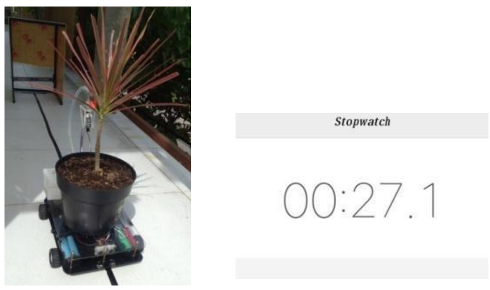

Figure 24: Testing the Robot Motor Speed

Table 7 presents the outcomes of the speed testing conducted on the robot motor under different load conditions.

Table 7.Robot Motor Speed Testing

No.	Total Load (Kg)	Travel Time (seconds)
1.	No Load	25.2 seconds
2.	0.5 kg	25.9 seconds
3.	1 kg	26.3 seconds
4.	1.5 kg	27.1 seconds
5.	2 Kg	27.4 seconds
6.	2.5 Kg	27.7 seconds
7.	3 Kg	31.1 seconds
8.	3.5 Kg	34.1 seconds

Water Pump Testing

Water pump testing aims to determine the level of speed and volume of water flowing for watering plants. For this type of plant itself, it is not allowed to give water in large quantities. So it has been estimated, according to the needs of this ornamental plant, that it takes a volume of water as much as 30-40 ml per day. Watering the plants in the morning and evening has been successfully carried out with RTC timing. The water pump passes through the hose, and the water comes out through the sprayer so that the water can be spread on the potted plants properly at intervals of 1.5 seconds with a water volume of 15 ml. The conclusion is that the water pump can work well according to the programming done.

Blynk App Testing

Testing the Blynk application aims to determine the speed of sending data from the ESP8266 microcontroller to the smartphone application and can monitor remotely. The sensor reading results will be displayed on the Blynk application, as shown in Figure 26.

Based on the picture above, the system is able to read and display data on the Blynk application if it is connected to the internet network. The monitoring system using Blynk application can be said to be quite easy, because Blynk is not tied to a particular board or module. In Table 7, we can see the results of monitoring tests on the Bynk application.

Table 7. Testing Results of Data Displayed in *Blynk*

From the test results in table 7, it can be seen that the system can display data on the Blynk application properly

Table 7. Testing Results of Data Displayed in *Blynk*

Hours	Time interval	Battery	Light (Lux)	Temperature (0C)	Description
07.00	0	8,25V (100%)	6,43	24,3	Starting position
08.00	60 minutes	8,23V (100%)	10,53	27,3	Starting position
09.00	60 minutes	7,47V (91%)	224,2	27,8	Starting position
09.06	6 minutes	8,03 (97%)	213,75	28,10	Moving forward
11.00	114	6,77V (82%)	376,56	31,10	Berdian
11.06	6 minutes	6,49V(79%)	19,51	31,10	Moving Backward (to the starting position)
11.36	30 minutes	8,20 (100%)	31,74	31	Moving
11.48	12 minutes	7,64V (93)%	401,34	31,50	Stand still
12.35	37 minutes	6,44V (82%)	244,87	32,00	Moving Backward (to the starting position)
13.00	25 minutes	8,15V (99%)	32,36	31,59	Starting position
14.00	60 minutes	8,20 (100%)	69,99	31,60	Starting position
15.00	60 minutes	8,22V(100%)	72,85	32,50	Starting position
16.00	60 minutes	8,28V(100%)	67,51	33,10	Starting position
17.00	60 minutes	8,03V(100%)	6,04	30,2	Starting position

Here in table 8, there is a list of overall system functional testing and its success rate. In Table 8, the data illustrates that the functional achieved a success rate of 100%. The system effectively collects data from sensors integrated with the ESP8266 microcontroller and accurately communicates this data to the Blynk application. Moreover, the system is designed to monitor indoor potted ornamental plants that thrive in semi-lit environments. The reliability of the sensor readings is noteworthy, indicating the system's capability to function as intended. Consequently, it can be deduced that the tool operates efficiently as a whole.

In Table 8, the data illustrates that the functional achieved a success rate of 100%. The system effectively collects data from sensors integrated with the ESP8266 microcontroller and accurately communicates this data to the Blynk application. Moreover, the system is designed to monitor indoor potted ornamental plants that thrive in semi-lit environments. The reliability of the sensor readings is noteworthy, indicating the system's capability to function as intended. Consequently, it can be deduced that the tool operates efficiently as a whole.

Table 8.Overall System Functional Testing

No.	Test Item	System Functional	Description
1.	Testing the photodiode sensor	Whether the system can detect the line as a robot path to move back and forth that has been determined by the owner	Successful
2	Testing the ultrasonic sensor	Whether the system can read the distance to an object that prevents the robot from moving come forward.	Successful
3	Tests on the BH1750 language sensor and sensor DHT22	Does the system successfully measure light intensity, temperature and humidity so that the plants are supplied with the light they need?	Successful
4	Testing for WiFi connectivity ESP8266	Whether the system successfully sends plant monitoring data to the smartphone application	Successful
5	Testing the system connected the application	Whether the system successfully connects with the blynk app properly	Successful

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Growth Analysis of Tricolour Plants

The study was initiated by planting three tricolor plants in a 7:3 ratio mixture of alluvial and humus soil. These plants were subjected to three different care methods: automated care with robot assistance, manual care, and stationary treatment. The research findings indicated notable differences in plant characteristics such as height, leaf count, and leaf width among the different care methods. Specifically, plants under robotic care exhibited the most significant improvement in leaf count compared to those receiving manual care and stationary treatment. However, the impact on plant height and leaf width was relatively minor.

The difference between the three plants can be clearly seen in the *display* or visual appearance of the plant or can be observed from the color of the leaves and the overall condition of the plant. The following table explains the different effects on these plants.

Table 9.Observation Results of Visual Display of Plants

	Description
Treatment with Robots	The results of observations on plants that use robots show that plant leaves look more normal, plant appearance is good, and plants do not experience many changes seen with brighter colors. For three weeks, no dead leaves were seen. In the third week, the color of the leaves looked wilted. The results of observations show that this plant has a dominant red leaf color with a bright color Whiteish green in the center of the leaves.
Manual care	The results of observations on these plants, leaf color, and visual appearance are almost the same as when using robots. However, some of this plant's leaves look yellowish red, the tips of the leaves are slightly dry, and the old leaves wilt faster than plants that use robots.
Plant Position Stays in Place	The observations of this plant in the last three weeks show that the leaves look greener. The plant still looks display-worthy, but the color changes from red to predominantly green. On old leaves, the tips dry quickly with a brownish color.

The variations in leaf color and the overall vitality of D. Marginata Tricolour plants suggest that the treatment with robots and manual care yields similar results. However, plants positioned to receive varying light exposure, moving from shaded areas to light, displayed better quality than plants exposed continuously to direct sunlight at a fixed point.

Figure 27 shows a visual display of the tricolor plant in week 2. The environmental conditions, plant treatment, and watering volume were found to significantly impact various observed variables, particularly in the appearance of leaf color. Despite all three sets of plants being considered display-worthy, the ones cared for by robots exhibited superior quality compared to those maintained manually by humans or placed in a fixed position. This highlights the effectiveness and practicality of using robotics in plant maintenance. Robots are beneficial as they are programmed with customized standards tailored to each plant's requirements. From regulated watering volumes to automatically adjusting light exposure, robots eliminate plant owners' need for constant manual intervention.

(a) (b) (c)

Figure 27: Visual display of the *Tricolour* Plant:
(a) Robotic Maintenance (b) Manual Maintenance (c) Plant Stays in Place

CONCLUSIONS

The design of a smart plant pot with an ornamental plant monitoring system with the concept of applying a line follower robot as a plant pot transportation can help the process of caring for ornamental plants. In this case the robot as a vehicle that transports indoor ornamental plants looking for light. This system can read the sensors and monitor the plants.

The study outlines the error margin of each sensor used in monitoring indoor ornamental plants, indicating slight inaccuracies with the light sensor at 1.675%, temperature sensor at 1%, and air humidity sensor at 7%. Despite these errors, the robot successfully transmits monitoring data to the Blynk application with a high accuracy level of 98%, provided a stable internet connection is maintained. The proposal to enhance the system by integrating a soil moisture sensor for regulating plant hydration levels is commendable, as it addresses a crucial aspect of plant care.

Furthermore, the suggestion to incorporate a Li-po battery for increased durability and a relay module for scheduled device activation aligns with improving the efficiency and practicality of the system. These additions would help optimize energy consumption and automate plant maintenance, enhancing the overall functionality and reliability of the monitoring system.
Overall, the recommendations for system development showcase a thoughtful consideration of improving data accuracy, operational efficiency, and sustainability in indoor plant care management.

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