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STM32-based IoT Monitoring System for an Indoor Plant

Khamil. K. N[1*], Khoo Y.Z[1], Isa. A.N[2]

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Abstract: There was a rise in interest in the horticulture industry when the pandemic started. Gardening became pleasurable and calming activity. However, not everyone is born with a green thumb. Many of us lack understanding about plant care, such as how much water we need to water the plant and the best luminance for the plant. This project aims to develop a system with a soil moisture sensor used to calculate the indoor plant's soil moisture percentage and a digital light intensity sensor applied to estimate the plant's luminance need using STM32 based microcontroller. The soil moisture value and luminance will be shown on the sensor's built-in OLED. All parameters will be sent to the user via a Wi-Fi connection established between the mobile phone and the ESP8266. As a result, the plant status was monitored using Blynk apps through the smartphone by the designated user. These promising results are presented as one of the main achievements of this work and help the plant community better monitor their plant health.

Keywords: indoor plant, plant monitoring, IoT, Blynk, STM32 platform.

1. Introduction

During the COVID-19 lockdown worldwide, home gardening and plant owners rapidly increase as a coping mechanism and as a way to pass the time. According to The Guardian, the wave of new plant owner enthusiast has led to retail sales growth in the horticulture industry [1]. It also an effort to keep access for fresh food when the panic buying among people that led to shortages in grocery store [2][3]. Study on the impact of gardening in times of stress shows that mental resilience of those who gardened was statistically significantly higher than the online community [4]. However, there is yet a method or any easy assessment that can be used for this new house plant beginner without having to worry about over watering, unbalance pH for the plant's soil and others. It is important to understand the relationship between our plants and the variable weather and its climate, hence the better the plants can thrive with a sustainable horticulture practice.

One of the most vital variables influencing plant growth is sunlight. Plant requires the sunlight in order to use it as the energy for photosynthesis process [5]. And if plants do not receive enough sunlight, they will not grow at their most rate or reach their most potential [6]. The photosynthesis process changes the light into a chemical reaction which separated the oxygen and hydrogen and carbon dioxide into sugar. Which goes into the rules of thumb, 1% of light generated a plant growth and resulting 1% increase of yield [6].

[1] *Advance Sensor and Embedded Control Research Group (ASECs), Fakulti Kejuruteraan Elektronik Dan Kejuruteraan Komputer (FKEKK), Universiti Teknikal Malaysia Melaka, Durian Tunggal, 76100,Melaka, Malaysia*
[2]*Hospital Melaka, Jalan Mufti Haji Khalil, 75400 Melaka*
**Corresponding Author*
ORCID ID : 0000-0003-4458-993X
Corresponding Author Email: nisa@utem.edu.my

In previous investigation by M. S. Kumar, T. R. Chandra, D. P. Kumar, and M. S. Manikandan (2016) has demonstrated a monitoring system using a low-cost homemade soil moisture sensor and Arduino UNO. The proposed system aimed to measure the soil moisture by verifying the condition of soil and get information about the quantity of water that need to be supplied for cultivation [7]. Similarly, A. Na, W. Isaac, S. Varshney, and E. Khan (2017) presented an IoT based system for continuous measurement and monitoring of temperature, soil moisture and relative humidity which monitor the assorted environmental parameters like temperature, humidity and soil moisture needed for the expansion of crops [8]. However, the system examined a pH value of the soil to help characterized the soil. The temperature, soil moisture and the pH values can easily access from the smartphones as it uses a cloud-based server for data acquisition.
González-Teruel, J. D et al (2019) designed and calibration of a low-cost SDI-12 soil moisture sensor [9]. An efficient way for optimal irrigation management is to measure the soil water with sensors. However, most of the farmer cannot afford due to the expensive commercial sensor. This new capacitive soil moisture sensor has incorporated SDI-12 communication and calibrated in three different soil to improves its accuracy.

However, Singh, P et al (2017) have used an Arduino-based smart irrigation with multiples sensor such water flow sensor, soil moisture sensor, temperature sensor and ESP8266 Wi-Fi module [10]. The developed system interacts with numerous environmental elements such as soil moisture, temperature, and the quantity of water to give further understanding the needs of the crops. All the results were monitored and linked to an interactive webpage that displays as real-time data. Likewise, Siddagangaiah, S (2016) presents a novel approach to IoT based plant health monitoring system using Arduino UNO development boards and connected the system to the Ubidots IoT cloud platform [11]. The system also measured the environmental elements such as temperature, humidity, and light intensity that have influence on the growth on plants. Vimal, P. V et al (2018) presented a continuous monitoring of environmental factors such as temperature, humidity, soil moisture, light intensity, soil pH required for a greenhouse system to promote optimal plant development [12]. Light dependent resistor (LDR) and pH sensor are the main sensor used where the data were sent to the mobile phone through offline or online using a GSM modem. The current condition of the environmental parameters was sent via short messaging system (SMS). When the sensor value surpasses a certain level, the designated user will receive an alert to monitor their plants condition through mobile phone. Based on all the above findings, there is yet a system that have incorporate an IoT-based indoor plant monitoring system will be implemented to detect environmental variables such as soil moisture and light intensity that influence the growth of the plants. The ESP8266 collects and transmits data, which may be automatically linked to a mobile phone app that displays real-time data as well as standard values for indoor plant characteristics as listed in the Table 1. Light is a crucial parameter that supplies the energy required for plants to produce food. The quantity of light is typically measured in foot-candles (ft-c) or in lux. The inside of a well-lit home is frequently less than 100 ft-c, but outside light intensity on a bright sunny day might approach 10,000 ft-c. Because 1 ft-c equals 10.8 lux, the amount of light for the indoor plants that will be the subject of my research will range from 185 ft-c to 557 ft-c [13].

Table 2. List of components used for the system.

No	*Module/Component*
1	SPST Push Button Switch
2	LED
3	SSD1306 OLED
4	BH1750 Digital Light Intensity Sensor
5	FC-28 Soil Moisture Sensor
6	LM1117
7	Tactile Switch
8	Potentiometer
9	ESP8266 (ESP12)
10	STM32F103C8T6

Table 1. Light and Water Required by Different Plant [18]

Botanical Name	*Common Name*	*Light*	*Water*
Pachira Aquatica	Money Tree	Bright, indirect light	Water when the soil is almost completely dry at top
Ficus Lyrata	Fiddle Leaf Fig	Indirect light	Keep the soil moist, but let at least 1 inch of soil dry out before watering again
Ficus Elastica	Rubber Plant	Bright, indirect sun light	Watering it about 1 to 2 times a week. Let the soil dry on top before watering
Strelitzia Nicolai	Giant Bird of Paradise	Indirect light	Keep soil moist
Dracaena Massangeana	Dracaena Corn Plant	Bright, indirect light	Water when soil becomes slightly dry at the top
Chamaedorea Seifrizii	Bamboo plant	Like all light except direct sun light	Keep soil moist, but be sure to have drainage for the plant
Philodendron Hederaceum	Heartleaf Philodendron	Medium light, indirect light	Keep soil moisture at all times
Monstera Deliciosa	Monstera	Bright, indirect light	Water whenever the soil starts to dry out
Hypoestes Phyllostachya	Polka Dot Plant	Indirect sun light	Well-drained and moist soil

After rigorous literature search, the circuit is simulated in Proteus software which first in schematic and then reconstructed the schematic circuit on the breadboard in 3D design, which help for easier assessment before developing the prototype. All the components and module used for developing the system are in Table 2, and Fig. 1, Fig. 2, schematically displayed the component listed.

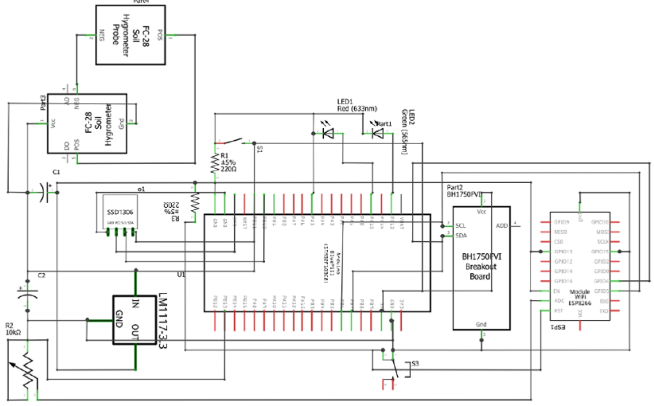

Fig. 1. System's schematic circuit design

For this system, STM32 blue pill will be used as the primary microcontroller and programmed using the Arduino IDE software. The function of soil moisture is to sense the level of moisture in the soil while digital light intensity is used to calculate the luminance hitting on the plants. Soil moisture value and light intensity will send to the user's mobile phone using ESP8266 by connecting to the WI-FI. The main sensor of the system will be the

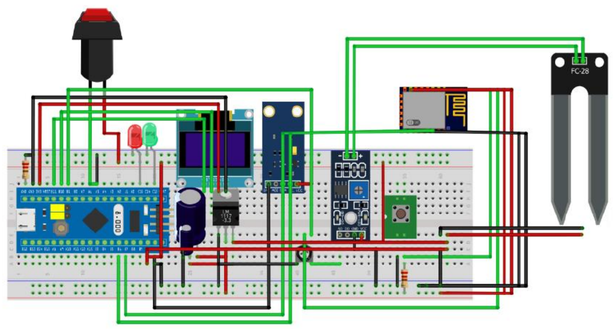

Fig. 2. Proteus Schematic Diagram in 3D design.

For this system, STM32 blue pill will be used as the primary microcontroller and programmed using the Arduino IDE software. The function of soil moisture is to sense the level of moisture in the soil while digital light intensity is used to calculate the luminance hitting on the plants. Soil moisture value and light intensity will send to the user's mobile phone using ESP8266 by connecting to the WI-FI. The main sensor of the system will be the soil moisture sensor and BH1750.

Guidelin

The fork-shaped probe, which has two exposed conductors, functions as a variable resistor (like a potentiometer) whose resistance changes with the amount of water in the soil [17]. Therefore, since the resistance is related to the moisture content of the soil, if there are more water in the soil, this means less resistance. And if the water content is minimal, there will be a higher resistance in soil content. The output of the soil moisture sensor is based on the electrical conductivity or resistance of the soil, and hence, with different input voltages for the soil moisture sensor will result in varied output voltages.

Fig. 3. Soil Moisture sensor of the system.

As a result, the soil moisture reading may have tolerance. To keep the range of the soil moisture value from becoming too wide, when the sensor is powered on, the lowest soil moisture value (without soil) is set as a reset. Thus, the system will integrate an OLED to display the condition of the plant. The other sensor used in this system, BH1750 digital light intensity, used to measure the plant's luminance. It employs the I2C communication standard to interface with a microcontroller and uses a very little amount of current.

To detect light, this sensor employs a photodiode; a P-N junction semiconductor. When lights are detected, electron-hole pairs form in the depletion area. Hence, the photodiode generates energy due to the internal photoelectric effect. The amount of power generated is proportional to the intensity of the light. The Op amp incorporated in the sensor will converts this electricity into voltage [7]. Therefore, the system can be programmed to monitor certain level of luminance. When the light intensity is more than 2000 lux and less than 4000 lux and the soil moisture percent is between 100% - 40%, the OLED will show the smiling emoticon. Otherwise, it will show the crying emoticon. All data from the soil moisture sensor and digital light intensity sensor will be received by the ESP12 and sent to the user through WI-FI. Hence, the user can check the soil and light condition on a mobile phone. The system will incorporate Blynk platform for online data acquisition monitoring. The coding for the STM32 is presented in the appendix section.

As for the operating voltage for the ESP12 is between 3.0V to 3.6V and the input voltage for the project is 5V. A LM1117, voltage regulator is used to decrease the input voltage for the ESP12 to prevent the ESP12 damage due to the higher voltage supply between 5V to 3.3V. The maximum analog input for the ESP12 is only 1V, and thus the potential is used to modify the input voltage from the FC-28 soil moisture sensor before connecting it to the ESP12 ADC pin.

3. Results

The process flow of the system is shown in Fig 4. The circuit prototype was achieved according to specification detailed in previous section, shown in Fig.5 When the power is supplied to the sensor, the red LED will light up, and the plant sensor will calibrate the FC-28 soil moisture sensor by measuring the present condition (without soil) as the lowest soil moisture per cent, which is 0%.

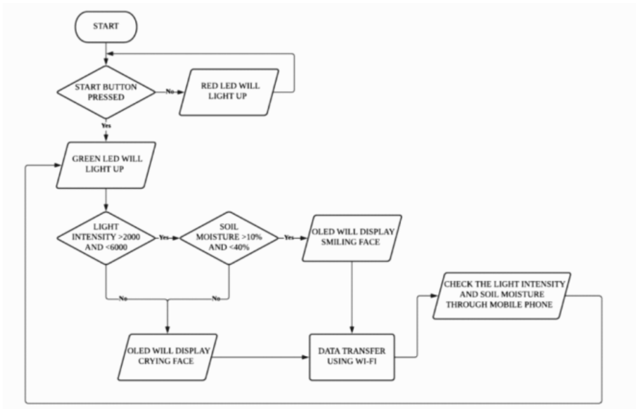

Fig. 4. System's process flow

The user needs to press the SPST Button Switch to make this sensor function, and the green LED will light up. Once the plant sensor is activated, the ESP8266 (ESP12) will connect to the WIFI, and users can monitor the data acquisition instantly. The BH1750 digital light intensity sensor used in this system will measure the plant's luminance. For safety purposes, a tactile switch was placed to the reset pin on the ESP12. And this button is used to reset the connection between the WIFI connection and the ESP12.

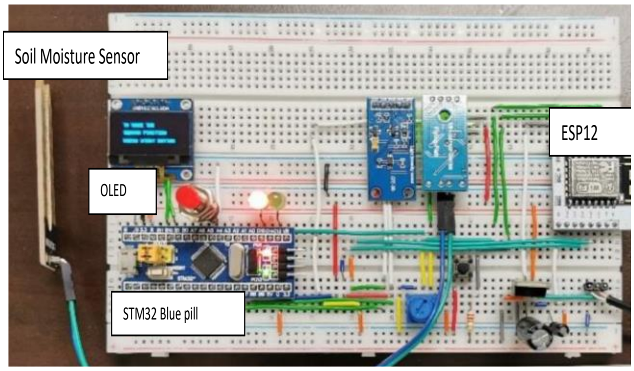

Fig. 5. Prototype of the circuit

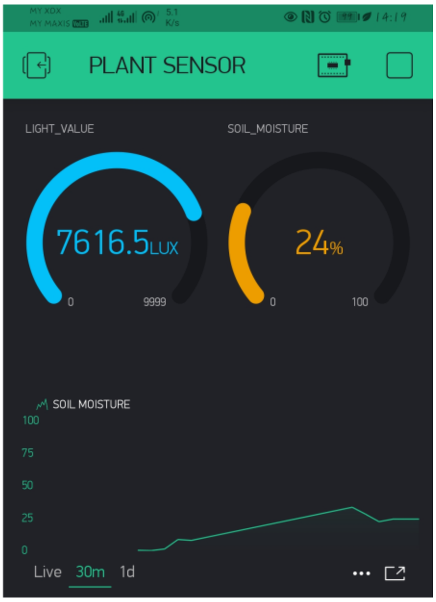

Fig. 6. Blynk Data Acquisition Online Monitoring

As seen in Fig. 6, the app's dashboard gave the lux level and the percentage value for the plant owner to easily monitor their plant. The condition of soil and light intensity were programmed according to the specification listed in Table 3 in the Appendix A for the OLED display and the coding's are presented in Appendix B.

The soil moisture's level was monitored for over five days, as shown in Fig 7. The graph depicts the changes in soil moisture value from the starting point to the wilting point and the shift in soil moisture level after watering it. Initially, the system's show the soil moisture at 31%, but over a day and a half, the soil moisture percentage drops 9% or 0.6% for each hour. Therefore, during day two, the plant has started to wilt due to lack of water. Once the plant was watered, the graph started to rise again. The soil moisture percentage is limited to 40% to avoid overwatering the plant. However, the outcome may change based on differences in environmental conditions such as temperature and humidity.

4. Conclusion

In summary, our study highlights a successful approach for an indoor plant monitoring system with smartphone apps integration. It can give an accurate approximate of luminance required, especially for a heavy-shade plant, by using a light intensity sensor. It also measures the soil moisture range for the plant through a soil moisture sensor and is displayed by an OLED using an emoticon to show its level of moisture and luminance. The plant status was monitored using Blynk apps through the smartphone by the designated user. These promising results are presented as one of the main achievements of this work and help the plant community better monitor their plant health.

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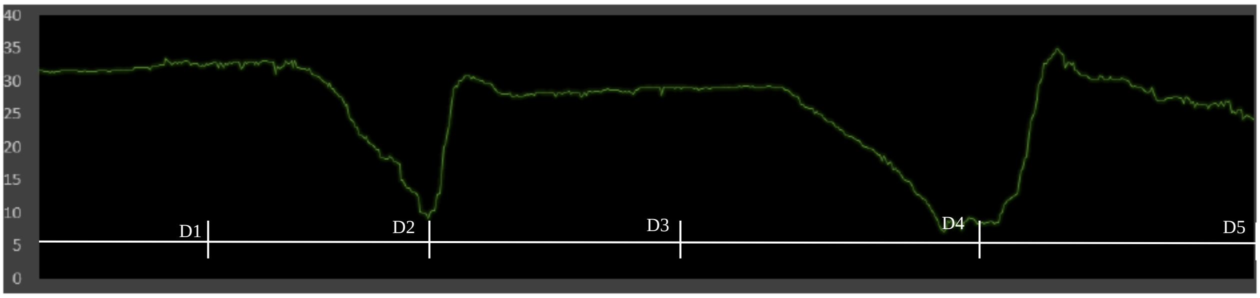

Fig. 7. Five days experimental data from Blynk online monitoring.

Appendix A.

Table 3. Display on OLED for Various Soil Moisture and Light Intensity

Soil Moisture (%)	*Light Intensity (LUX)*	*OLED Display*	
<10%	<2000	Crying Emoticon Soil_Moisture: Too Low Light_Value: Too Low	
>40%	<2000	Crying Emoticon Soil_Moisture: Too High Light_Value: Too Low	
<10%	>6000	Crying Emoticon Soil_Moisture: Too Low Light_Value: Too High	
>40%	>6000	Crying Emoticon Soil_Moisture: Too High Light_Value: Too High	
>10 and <40	<2000	Crying Emoticon Soil_Moisture: Suitable Light_Value: Too Low	
<10	>2000 and <6000	Crying Emoticon Soil_Moisture: Too Low Light_Value: Suitable	
>40	>2000 and <6000	Crying Emoticon Soil_Moisture: Too High Light_Value: Suitable	
>10 and <40	>2000 and <6000	Smiling Emoticon Soil_Moisture: Suitable Light_Value: Suitable	

Appendix B.
Coding Program for STM32 platform

```
#include <ErriezBH1750.h>

U8G2_SSD1306_128X64_NONAME_F_SW_I2C u8g2(U8G2_R0,PB10,PB11,U8X8_PIN_NONE);
BH1750 lightMeter(LOW);

int RedLED = PC15;
int GreenLED = PC13;
int StartButton = PA5;
int soilMoisture = 0;
int soilMoistureSensor = PB1;
int initialMoisture;
uint16_t lux;

const unsigned char PROGMEM smilingFace[] = {
0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0xE0, 0x07, 0x00,
0x00, 0x1C, 0x38, 0x00, 0x00, 0x03, 0xC0, 0x00, 0x80, 0x01, 0x80, 0x01, 0xC0, 0x00, 0x00, 0x03,
0x60, 0x00, 0x00, 0x06, 0x20, 0x00, 0x00, 0x04, 0x10, 0x00, 0x00, 0x08, 0x10, 0x00, 0x00, 0x08,
0x10, 0x1C, 0x38, 0x08, 0x08, 0x22, 0x44, 0x10, 0x08, 0x22, 0x40, 0x10, 0x08, 0x00, 0x00, 0x10,
0x08, 0x00, 0x00, 0x10, 0x08, 0x00, 0x00, 0x10, 0x08, 0x00, 0x00, 0x10, 0x10, 0x08, 0x10, 0x08,
0x10, 0x30, 0x0C, 0x08, 0x10, 0xC0, 0x03, 0x08, 0x20, 0x00, 0x00, 0x04, 0x60, 0x00, 0x00, 0x02,
0xC0, 0x00, 0x00, 0x03, 0x80, 0x01, 0x80, 0x01, 0x00, 0x03, 0x40, 0x00, 0x00, 0x1C, 0x38, 0x00,
0x00, 0xE0, 0x07, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00
};
const unsigned char PROGMEM cryingFace[] = {
0x00, 0x00, 0x00, 0x00, 0x00, 0xFC, 0x3F, 0x00, 0x00, 0x0F, 0xF0, 0x00, 0x80, 0x01, 0x80, 0x01,
0xE0, 0x00, 0x00, 0x07, 0x30, 0x00, 0x00, 0x0C, 0x18, 0x00, 0x00, 0x08, 0x08, 0x00, 0x00, 0x18,
0x0C, 0x00, 0x00, 0x30, 0x04, 0x00, 0x00, 0x20, 0x06, 0x00, 0x00, 0x60, 0x02, 0x04, 0x20, 0x40,
0x02, 0x0E, 0x70, 0x40, 0x03, 0x1F, 0xF8, 0xC0, 0x03, 0x0E, 0x70, 0xC0, 0x03, 0x00, 0x00, 0xC0,
0x03, 0x00, 0x00, 0xC0, 0x03, 0x00, 0x00, 0xC0, 0x03, 0x00, 0x00, 0xC0, 0x02, 0xF0, 0x0F, 0x40,
0x02, 0x1C, 0x38, 0x40, 0x06, 0x06, 0x60, 0x60, 0x04, 0x02, 0x40, 0x20, 0x0C, 0x00, 0x00, 0x30,
0x08, 0x00, 0x00, 0x10, 0x18, 0x00, 0x00, 0x08, 0x30, 0x00, 0x00, 0x0C, 0xE0, 0x00, 0x00, 0x07,
0x80, 0x01, 0x80, 0x01, 0x00, 0x0F, 0xF0, 0x00, 0x00, 0xFC, 0x3F, 0x00, 0x00, 0x00, 0x00, 0x00
};

void setup() {
  // put your setup code here, to run once:
  pinMode(StartButton,INPUT);
  pinMode(RedLED,OUTPUT);
  pinMode(GreenLED,OUTPUT);
  pinMode(soilMoistureSensor, INPUT_ANALOG);

  Serial.begin(9600);
  u8g2.begin();
  u8g2.clearBuffer();
  u8g2.setFont(u8g2_font_profont10_mf);
   Wire.begin();
   lightMeter.begin(ModeContinuous, ResolutionHigh);
   lightMeter.startConversion();

   delay(100);
   initialMoisture = analogRead(soilMoistureSensor) + 15;

 }

 void loop() {
   // put your main code here, to run repeatedly:
   if (digitalRead(StartButton) == HIGH){
     digitalWrite(GreenLED,HIGH);
     digitalWrite(RedLED,LOW);

     while(true){
       delay(200);
       soilMoisture = map(analogRead(soilMoistureSensor), initialMoisture, 500, 0, 100);
       if (lightMeter.isConversionCompleted()) {
         lux = lightMeter.read();
       }
       u8g2.clearBuffer();
       u8g2.drawStr(0,8,"Soil_Moisture (%)=");
       u8g2.setCursor(90,8);
       u8g2.print(soilMoisture);
       u8g2.drawStr(0,18,"Light_Value (lux)=");
       u8g2.setCursor(90,18);
       u8g2.print(lux/2);
       u8g2.print(".");
       u8g2.print(lux % 10);
      if (soilMoisture >= 10 && soilMoisture <= 40 && lux/2 >= 2000 && lux/2 <= 6000){
        u8g2.drawXBMP(0, 28, 32, 32, smilingFace);
        u8g2.drawStr(40,30,"Soil_Moisture...");
        u8g2.drawStr(40,40,"Suitable");
        u8g2.drawStr(40,52,"Light_Value...");
        u8g2.drawStr(40,62,"Suitable");
      }
      else if (soilMoisture < 10 && lux/2 >= 2000 && lux/2 <= 6000){
        u8g2.drawXBMP(0, 28, 32, 32, cryingFace);
        u8g2.drawStr(40,30,"Soil_Moisture...");
        u8g2.drawStr(40,40,"Too Low");
        u8g2.drawStr(40,52,"Light_Value...");
        u8g2.drawStr(40,62,"Suitable");
      }
      else if (soilMoisture >40 && lux/2 >= 2000 && lux/2 <= 6000){
        u8g2.drawXBMP(0, 28, 32, 32, cryingFace);
        u8g2.drawStr(40,30,"Soil_Moisture...");
        u8g2.drawStr(40,40,"Too High");
        u8g2.drawStr(40,52,"Light_Value...");
        u8g2.drawStr(40,62,"Suitable");
      }
      else if (soilMoisture >= 10 && soilMoisture <= 40 && lux/2 < 2000){
        u8g2.drawXBMP(0, 28, 32, 32, cryingFace);
        u8g2.drawStr(40,30,"Soil_Moisture...");
        u8g2.drawStr(40,40,"Suitable");
        u8g2.drawStr(40,52,"Light_Value...");
        u8g2.drawStr(40,62,"Too Low");
      }
      else if (soilMoisture >= 10 && soilMoisture <= 40 && lux/2 > 6000){
        u8g2.drawXBMP(0, 28, 32, 32, cryingFace);
        u8g2.drawStr(40,30,"Soil_Moisture...");
        u8g2.drawStr(40,40,"Suitable");
        u8g2.drawStr(40,52,"Light_Value...");
        u8g2.drawStr(40,62,"Too High");
      }
      else if (soilMoisture < 10 && lux/2 < 2000){
        u8g2.drawXBMP(0, 28, 32, 32, cryingFace);
        u8g2.drawStr(40,30,"Soil_Moisture...");
        u8g2.drawStr(40,40,"Too Low");
        u8g2.drawStr(40,52,"Light_Value...");
        u8g2.drawStr(40,62,"Too Low");
      }
      else if (soilMoisture < 10 && lux/2 > 6000){
        u8g2.drawXBMP(0, 28, 32, 32, cryingFace);
        u8g2.drawStr(40,30,"Soil_Moisture...");
        u8g2.drawStr(40,40,"Too Low");
        u8g2.drawStr(40,52,"Light_Value...");
        u8g2.drawStr(40,62,"Too High");
      }
      else if (soilMoisture > 40 && lux/2 < 2000){
        u8g2.drawXBMP(0, 28, 32, 32, cryingFace);
        u8g2.drawStr(40,30,"Soil_Moisture...");
        u8g2.drawStr(40,40,"Too High");
        u8g2.drawStr(40,52,"Light_Value...");
        u8g2.drawStr(40,62,"Too Low");

      }
      else if (soilMoisture > 40 && lux/2 > 6000){
        u8g2.drawXBMP(0, 28, 32, 32, cryingFace);
        u8g2.drawStr(40,30,"Soil_Moisture...");
        u8g2.drawStr(40,40,"Too High");
        u8g2.drawStr(40,52,"Light_Value...");
        u8g2.drawStr(40,62,"Too High");
      }

      u8g2.sendBuffer();
      delay(50);
    }
  }

  else{
    digitalWrite(RedLED,HIGH);
    digitalWrite(GreenLED,LOW);
    u8g2.drawStr(19,21,"TO MAKE THE");
    u8g2.drawStr(20,35,"SENSOR FUNCTION");
    u8g2.drawStr(20,50,"PRESS START BUTTON");
    u8g2.sendBuffer();
  }
}
```


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Author contributions

Khamil. K. N: Conceptualization, Writing-Original draft preparation and Data Analysis
Khoo Y.Z: Software validation., Field study

Conflicts of interest

The authors declare no conflicts of interest.

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