Smart Greenhouse Monitoring and Maintenance System for Productive Urban Farming Markets

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ABSTRACT

Urbanization rate in the Philippines is continuously rising. While there is a growing demand for green spaces in highly urbanized areas, maintaining urban landscapes is a recurring challenge that must be fulfilled in order to achieve sustainable living in busy cities. The Smart Greenhouse Monitoring and Maintenance System for Productive Urban Farming Markets monitors and controls the environmental parameters of a greenhouse on a regular basis. The glasshouse is planted with edible plants, thus making the greenhouse equivalent to an urban farming market. It automates ventilation, lighting, and irrigation of the plants inside the greenhouse. Also, it provides real-time data displayed in a graphical user interface. As a result, it maximizes green space in urban areas upon its installation in condominiums and apartments and allows urban residents to grow their own produce and ensure they are organically grown and freshly harvested for their own consumption.

Keywords: *urbanization, greenhouse, smart monitoring and maintenance, urban farming market*

CHAPTER 1

THE PROBLEM AND ITS BACKGROUND

Background of the Study

Urbanization in the Philippines has grown as decades pass by. As shown in Figure 1.1, urbanization level in 2015 was at 51.2 percent, 5.9 percent higher than the recorded urbanization rate in 2010 and 9.5 percent higher than that of the previous decade. Urbanization directly contributes to a high level of fragmentation of urban green spaces, thus resulting to various socioeconomic and environmental problems.

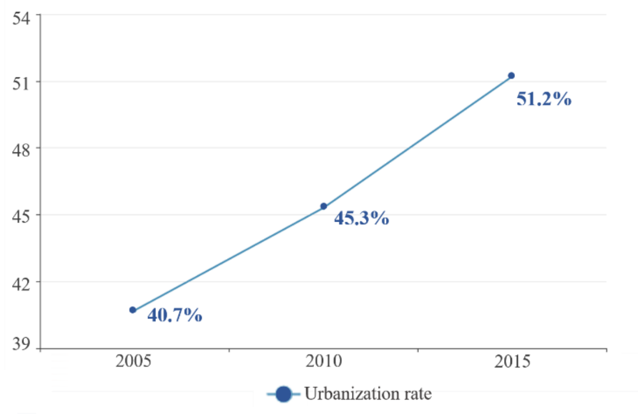

Figure 1.1. Urbanization in the Philippines from 2005-2015

According to the Department of Environment and Natural Resources-National Capital Region Production Forest Management Section chief, Arturo Calderon, during the briefing of the DENR-NCR on Philippine Arbor Day in June 2019, World Health Organization sets 9.5 square meters per capita as the standard size of green space for healthy urban living. Calderon said that NCR lacks about 80.6 hectares of green space, wherein Caloocan, Malabon, Mandaluyong, Manila, Navotas, Pasay, Pasig, and San Juan cities, as well as the Pateros municipality, are the areas in NCR that lack green space. Local government units and private companies continuously enact initiatives to counter the problem with scarcity of green spaces in urban areas.[1]

Agriculture is thought to be the human species' basis of life as it is the primary source of food grains and alternative raw materials. Agricultural growth is necessary in order to improve the country's economic condition. Unfortunately, most farmers still use traditional farming practices, leading to low crop and fruit yields. Agricultural problems have always hindered the country's development. Agricultural development should follow the path of modern agriculture. With the rapid economic development, more and more attention has been paid to the research and application of agricultural technology, particularly the greenhouse has become an important part of efficient farming.

Greenhouse is a building or location for the cultivation of small plants and vegetables. The area under the green house is covered by glass or translucent plastic roofs. In colder regions, this plays an important role for vegetation, as it is still very cold to take them outside. Greenhouse effect is basically a process in which specific greenhouse gases absorb infrared rays from sunlight, resulting in increased levels of carbon dioxide, thus helping to increase chlorophyll levels, resulting in impressive plant growth and yield.[2]

Urban landscaping through greenhouse construction offers visual beauty and relief and delivers ambient cooling benefits. Plants filter pollutants through photosynthesis and biofiltration, helps reduce risks of various diseases, and may provide sources of food for human consumption.

Accordingly, crop yield and quality are forcing agriculture and information industry to follow common goals of optimizing agricultural output while maintaining quality. Currently, domestic agricultural greenhouse management mainly uses a traditional manual management mode, which is based on experience to adjust light, temperature, humidity, irrigation, fertilization and artificial cultivation periodically and manually. This approach not only leads to higher costs of management, but also carries with it a number of problems, such as low efficiency of production, waste of resources and contamination of the atmosphere.

Environment is the driving force for the growth and health of plants. An understanding of climate factors that affect plant growth helps the grower to be aware of potentially harsh consequences due to improper plant care.

Temperature

Autotrophs should be exposed to a certain temperature range to maintain its health. If temperature goes above the appropriate range, plant enzymes become inactive and it would hinder growth. If ambient temperature falls below the range, ice would form within the tissues and block water that provides moist necessary for the plants to thrive.

Humidity

Plants exposed to a dry environment will restrict transport of nutrients and eventually wilt as it loses moisture. Under highly humid conditions, fungal diseases from air are likely to invade growing plants and ultimately restrict nutrient transpiration.

Light

Plants use energy from sunlight through a process called photosynthesis. Without adequate light, plants will grow weaker and leaves will turn into pale yellow. It is desired to place the plants in moderate shading in order to produce taller stems and larger leaves.

Soil Moisture

Plants will wilt if soil lacks a certain amount of moist, while overly moist substrate would result to leaching of nutrients and damaging of the roots. Therefore, water supplied to the plants should be at an appropriate level in order to avoid fatal effects to the plants.

However, maintaining greenhouse in busy cities imposes challenges. The grower is primarily faced with unattended monitoring of the plants due to time constraints. Likewise, human error such as improper irrigation often leads to low productivity. Hence, the researchers propose the construction of a greenhouse that is equipped with an autonomous control system that delivers the basic needs of plants in order that the grower will save in terms of costs and the plants will remain healthy.[3]

This study is an application of closed-loop control system and data analytics. The system will closely monitor and control the environmental parameters of a greenhouse on a regular basis. The real-time data obtained from the sensors will determine the appropriate actions that the system will perform and will be displayed in graphical format. Additionally, it will alert the user about the condition of the greenhouse when the appropriate signals are sent through the microcontroller.

In this study, a prototype of a greenhouse will be constructed. The system shall be able to autonomously monitor and regulate temperature, humidity, lighting, and soil moisture inside the greenhouse. The potential benefit of this study is to maximize urban spaces for urban markets, as well as turn parts of it for green spaces. Also, to motivate residents of urbanized areas such as condominiums and apartments to grow their own produce and ensure they are organically grown and freshly harvested for their own consumption and, in turn, inspire them to participate in uprising urban markets in society's efforts for sustainable living and development.

Statement of the Problem

Urban landscaping through greenhouse construction offers numerous benefits. Urban farming market may be achieved through greenhouse construction on condominiums and apartments, thus maximizing green spaces in urban areas. However, maintaining greenhouse in busy cities imposes challenges.

The following are some problems that this study will answer:

1. Researchers have shown the smart monitoring and maintenance system for productive urban farming markets. In the existing system, the grower is primarily faced with unattended monitoring of the plants due to time constraints. Thus, human error occurs and often leads to low productivity.
2. Having a greenhouse that is equipped with an autonomous control system that delivers basic needs of the plants will be cost-efficient and the plants will remain healthy. In the current system, agricultural greenhouse management mainly uses a traditional manual management mode.
3. In the manual system, higher costs are expected and carries with it a number of problems, such as low production efficiency, waste of water, and contamination of the atmosphere.

Objectives

a. General Objectives

The main objective of the study is to implement a smart greenhouse monitoring and maintenance system for productive urban farming markets.

b. Specific Objectives

The specific objectives of this study are as follows:

- To construct a greenhouse with an application of closed-loop control system;
- To monitor and control the environmental parameters of a greenhouse on a regular basis, such as temperature, humidity, lighting, carbon dioxide, soil moisture content;
- To design a water recycling mechanism to reuse the water used for irrigation;
- To provide an automated ventilation system that is controlled depending on the sensor values of humidity and temperature;
- To provide an automated lighting system on the greenhouse to sustain the health of the plants;
- To provide graphical user interface for a representation of the real-time data obtained from the sensors; and
- To provide an alert to the user about the condition of the greenhouse that was sent through the microcontroller.

Significance of the Study

The significance of this study is that urban spaces for urban markets will be maximized and will be converted to green spaces. This will also motivate residents of urbanized areas such as condominiums to grow their own produce food crops. And, to inspire condominium owners to invest on this greenhouse system because of its profit potential.

Scope and Limitations

This research will focus on providing a model of a smart greenhouse monitoring and maintenance system which will soon be laid out at urbanized areas such as condominiums and apartments. The researchers will be constructing a prototype of a greenhouse. The system monitors different parameters through the use of a soil moisture sensor—which regulates the amount of water being fed to the plants, a temperature/humidity sensor—responsible for adjusting the amount of ventilation in the greenhouse, and lastly, a light-dependent resistor—automating the intensity of the brightness of the installed lighting system depending on the detected luminescence within the environment.

Pertinent data such as current state of the installed lights, moisture of the soil, and humidity shall be recorded and consolidated on an application that shall be accessed by the owner of the greenhouse. These data obtained in an hourly and daily interval shall be converted into useful information that can be used to determine the quality and effectiveness of monitoring and maintenance of the greenhouse. Additionally, the system could be controlled through the application at any given time and the administrator can use it if deemed necessary.

The study is inclusive and limited only to the construction of a prototype of a greenhouse which exhibits the different integrations that have been previously stated.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Review of Related Literature and Studies

Automated Irrigation System Using Internet of Things Technology

Irrigation practices in India include ditch irrigation, terraced irrigation, drip irrigation, and sprinkler systems. Today's recurring problems with low agricultural productivity and decreased availability of water for agriculture can be reduced if automated farming irrigation systems are utilized. One setup of an irrigation system is equipped with rain gun mechanism for irrigation and solenoid valve which controls the flow of water. The solenoid valve opens when a signal, in this case, the soil moisture, is sent through the microcontroller. The valve will not close until the soil moisture level, as measured by the soil moisture sensor, reaches normal level. Then, a buzzer indicates that the valve must be opened, and an alert is sent to the connected mobile phone using GSM. Another setup includes distributed wireless communication sensors across the field. All sensory data are wirelessly transmitted to the base station and enter a decision-making program to send control commands to the irrigation control station. As a result, automated irrigation systems eliminate human error and save resources by reducing runoff from overwatering soils (Kansara et. al, 2015).[4]

Smart Maintenance Systems

Rivas-Sánchez et al. (2018) proposed a low-cost automated irrigation system for green walls. The vertical garden prototype consists of eight one square meter open-back cases fixed to a wall in Rabanales campus at the University of Córdoba in Spain. The *Lampranthus spectabilis* and *Aptenia cordifolia* species of plants which have similar water and sunlight exposure requirements were planted on either sphagnum moss or coconut coir with rice husk substrates. Irrigation pipes are located at the upper and middle areas of the module and are connected to an irrigation pump which is controlled by a relay actuator. Various sensors were interfaced with Arduino UNO equipped with ATmega328 microcontroller to obtain relevant data. FC-28 soil moisture sensors were installed in the upper and lower part of the green wall module to record the average soil moisture level, while relative humidity and temperature are measured using DHT-22 sensor. On the other hand, a light dependent resistor is used to determine the light intensity that reaches the vertical garden. Consequently, the YL-83 rain sensor is calibrated to switch the pump off when it rains and the YF-S402 water flow sensor provides an indication of water consumption by the green wall. The Raspberry Pi B+ stored data during the three-month experimental on a 16 GB Class 10 SD card. Data were collected through Internet using Transmission Control Protocol via ThingSpeak to present real-time data in graphical format. Environmental parameters such as temperature, humidity, hours of sunlight, substrate moisture, presence of rain, and flow of water can be viewed in a mobile application. As a result, the outputs correspond to the expected responses of the sensors such as the maximum values of humidity at a certain temperature, peak readings of light at noon, and fluctuations of substrate humidity in response to irrigation. Without additional field installation equipment fees, the irrigation system and the database cost about €58. The autonomous system helps in reducing water and energy consumption, optimizing quality growth of the plants, and resulting to maintenance cost savings in the future. The researcher suggests an implementation of a wireless system to the vertical garden and addition of new sensors such as those that monitor carbon dioxide, barometric pressure, conductivity of substrate, and temperature of soil and water.[5]

Greenhouse Monitoring and Automation System Using Microcontroller

Pradeep Kumar and Byregowda (2017) designed an automated system for green houses which is implemented in real time to monitor and control environmental factors such as temperature, light intensity, humidity and soil moisture, to alleviate the need for human intervention, and for consistent maintenance to enhance cultivation of crops and different plant species. They mentioned that developing a landscape maintenance schedule that provides for timely pruning, watering, mulching, pest control, and fertilizing when necessary, will promote individual plant health and ultimately protect and enhance the entire landscape. The system comprises of sensors, Analog to Digital Converter, microcontroller and actuators. When any of the abovementioned environmental parameters cross a threshold, which must be maintained for the proper cultivation of the crops, the sensors react to this change and the microcontroller reads this from the data at its input ports after being converted to a digital form by the Analog to Digital Converter. The microcontroller then performs the needed actions to maintain conditions to its threshold levels by employing relays until the strayed-out parameter has been brought back to its optimum level. Since a microcontroller is used as the heart of the system, it makes the set-up low-cost and effective, nevertheless. As the system also employs an LCD display for continuously alerting the user about the conditions inside the greenhouse, the entire set-up becomes user friendly. Thus, this system eliminates the drawbacks of the existing set-ups and is designed as an easy to maintain, flexible low-cost solution.[3]

Greenhouses, Home Gardens, and Sustainability

Home garden is an integrated system which comprises different things in its small area that produces a variety of foods and agricultural products including staple crops, vegetables, fruits, medicinal plants and so on. Home gardens, whether found in rural or urban areas, are characterized by a structural complexity and multi-functionality which enables the provision of different benefits to ecosystems and people. Home gardens are important social and cultural spaces where knowledge related to agricultural practice is transmitted and through which households may improve their income and livelihood (Agbogidi and Adolor, 2013).[6]

On Hoogerbrugge and Fresco's paper (1993), they pointed out that as a result of population growth and market integration, home garden functions shift gradually from subsistence production of a great variety of staple foods to commercial production of a few specialized horticultural crops, and, ultimately, perhaps to a source of leisure. As a result, the constraints and needs of home gardeners differ considerably depending on the function of the gardens. Any home garden program must define its target groups and the probable developments of their home gardens in the next decade. Home gardens are not only a low-input form of land use. Their survival may very well depend on increased but well-balanced use of environmentally safe inputs of fertilizer and nutrients, especially in Asia. Quality control of the products may be another area requiring further development, as many home gardens may be able to compete with commercial growers only through the quality and careful handling of (specialized) products. In the future, the environmental effects of increased biocide use in home gardens and processing of home garden products are of great importance and must be closely monitored.[7]

In Mitchell and Hanstad's study (2004), it examines the ways in which the poor can use small amounts of land to establish home gardens to advance important livelihood objectives. The paper considers the potential benefits of home gardens in light of policy, financial and cultural constraints, and provides a framework for planners to consider whether (and which) home garden interventions are appropriate for improving livelihoods of the poor.

The sustainable livelihoods approach seeks to increase the sustainability of the lives of the poor by promoting six core objectives: (1) more secure access to, and better management of, natural resources; (2) more secure access to financial resources; (3) a policy and institutional environment that supports multiple livelihood strategies and promotes equitable access to competitive markets; (4) better nutrition and health; improved access to high quality education, information, technologies, and training; (5) a more supportive and cohesive social environment; and (6) better access to basic and facilitating infrastructure (DFID 2001).

Home gardens represent an especially useful strategy for promoting sustainable livelihood objectives of the poor, including secure access to land and water, improved financial security, improved leverage in wage bargaining, improved nutrition, improved social status and political status, and better access to basic infrastructure.[8]

Synthesis of the Study

The integration of agriculture and technology has been an important innovation for humankind. The development of systems that minimizes human effort and cultivates healthy growth of crops automatically through these innovations encourages agricultural productivity when utilized and implemented correctly. Home gardens are proven to be a vital space where agricultural practice is utilized to uplift organic consumption by self-producing staple food, and thus promotes sustainability. Moreover, home gardens embolden the need for upholding sustainability in the uprising trend of urban markets as urbanization grows decade by decade.

With the use of modern technology and controlled environments utilizing components such as sensors, microcontrollers, automatic valves and the application of Internet of Things technology, human errors are eliminated, and resources are saved since enough consumption needed by crops are provided by controlled systems.

Additionally, the use of real-time data of different variables as mentioned in the studies above, as well as previous data collected by new irrigation and controlled environment systems is utilized to enhance the cultivation and productivity of systems, optimizing green spaces for sustainability and stimulate proper plant health.

Definition of Terms

Smart greenhouse – A structure with walls and roof made chiefly of transparent material, such as glass, in which plants requiring regulated climatic conditions are grown, wherein the environment is controlled and maintained automatically by technology.

Urban farming market – It is referred to as indoor and outdoor plant cultivation, to serve local inhabitants by processing them to distribute food in and around communities. The demand for this surged from the rise of urbanization among cities.

Edible plants – Edible plants are organisms from the vegetable kingdom suitable by nature for use as food especially for humans.

Temperature – It is the degree or intensity of heat present inside the smart greenhouse.

Humidity – It is a quantity representing the amount of water vapor in the smart greenhouse.

Light – It is the amount of sunlight that is present inside the smart greenhouse.

Soil Moisture – Soil moisture is the water stored in the soil and is affected by precipitation, temperature, soil characteristics, and irrigation in the smart greenhouse.

Drip irrigation – It is a method of controlled irrigation in which water is slowly delivered to the root system of multiple plants.

Pump – It is a mechanical device using suction or pressure to raise or move liquids.

Temperature and humidity sensor – This sensor is used to measure temperature and humidity in the smart greenhouse. Provides a way for temperature and humidity to be measured and recorded.

Light dependent resistor – This sensor is used to measure light in the smart greenhouse. Provides a way for light to be measured and recorded.

Soil moisture sensor – This sensor is used to measure soil moisture in the smart greenhouse. Provides a way for soil moisture to be measured and recorded.

Arduino MEGA **–** A microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. Data from the sensors are directly transmitted to this device. This microcontroller then transmits the device to the database and mobile application for the purpose of records and real-time checking.

Database – A database is a collection of information that is organized so that it can be easily accessed, managed and updated. Environmental parameters measured inside the smart greenhouse are recorded in the database and the users acquire these parameters through the graphical user interface which accesses the database.

CHAPTER 3

Smart Greenhouse Monitoring and Maintenance System

Abstract

The Smart Greenhouse Monitoring and Maintenance System provides autonomous irrigation, ventilation, and lighting to regulate the environmental parameters inside the greenhouse for urban farming market. The system is equipped with automated delivery of water for irrigating the plants, while the speed of the fan will change according to the temperature and humidity required to sustain the health of the plants. On the other hand, the lighting of the greenhouse will be determined according to the intensity of light sustained by the glasshouse. The system also includes a graphical user interface which displays real-time information in graphical format and alerts the user about the condition of the greenhouse.

Introduction

Urban landscaping provides numerous benefits. It offers visual relief, delivers ambient cooling benefits, filter pollutants, helps reduce risks of various diseases, and may provide sources of food for human consumption. The demand for occupying spaces in cities for landscaping in order to achieve sustainable living and development is continuously increasing. However, environment and time are crucial factors for the growth of plants. Low productivity of plants is often attributed to improper or lack of maintenance which are the most common issues faced by residents in urban areas.

Urban farming market may be achieved through greenhouse construction on condominiums and apartments, thus maximizing green spaces in urban areas. Greenhouse systems enable residents to grow their own produce which can be freshly harvested for their own consumption. Thus, this study aims to develop a control system that will measure and regulate temperature, humidity, light, and soil moisture of a greenhouse on a regular basis. An autonomous system that delivers the basic needs of the plants helps optimize plant quality and results to cost savings in the long run.

The ideal temperature for a greenhouse is 80 to 85 degrees Fahrenheit, or 26.7 to 29.4 degrees Celsius.[2] The ideal humidity for various types of greenhouse varies. However, as plants exposed to a dry environment will restrict transport of nutrients and eventually wilt as it loses moisture, and fungal diseases from air are likely to invade growing plants and ultimately restrict nutrient transpiration under highly humid conditions, 40% to 80% humidity is set as the appropriate humidity in the system. On the other hand, all vegetables require soil moisture between 41% - 80%.[9] Since the plants are placed inside the greenhouse, the external environment does not affect the environmental parameters inside the glasshouse.

Some of the vegetables that can be found in a Filipino marketplace set-up and the ideal vegetables to be planted on the smart greenhouse are as stated below together with the minimum soil depths for healthy growth:

- 4-5": chives, lettuce, radishes, other salad greens, basil, coriander
- 6-7": bush beans, garlic, onions, peas, mint, thyme
- 8-9": pole beans, carrots, cucumber, eggplant, fennel, leeks, peppers, spinach, parsley, rosemary
- 10-12": broccoli, okra, potatoes, sweet corn, squash, lemongrass

When combining several different types of plants in one pot, it is best to match plants that have a similar need for water and fertilizer. For example, rosemary, which likes hot and relatively dry conditions, would not be a good match with water-hungry cucumbers. To maximize space, you might want to combine a trailing plant with an upright plant.

Some plants actually grow better when grown near a compatible companion. On the other hand, some plants don't seem to grow as well when paired with certain plants. Sometimes the reasons are simple, but others are more mysterious. The list below offers good plant combinations—as well as combinations to avoid.

- Beans, carrots, squash
- Eggplant, beans
- Tomatoes, basil, onions
- Lettuce, herbs
- Spinach, chard, onions[10]

Methodology

There are various sensors that obtain the vital environmental parameters of the greenhouse. The DHT-22 sensor measures the temperature and humidity inside the greenhouse, while the light-dependent resistor measures the amount of light acquired by the glasshouse. Consequently, the soil moisture sensor module measures the wetness of the soil, and the pump is connected to the water supply to control irrigation. Data acquired will be transmitted to the microcontroller to determine the necessary actions and regulate the environmental parameters in the greenhouse. Data obtained from the DHT-22 sensor determines whether the installed fan must be turned on or off, while the light-dependent resistor will be programmed to control the lights installed inside the house. Consequently, the soil moisture sensor will trigger the pump which is connected at the water supply. Pertinent real-time data will be displayed in graphical format and alerts will be delivered to the concerned person. Figure 3.1 shows the system conceptual framework.

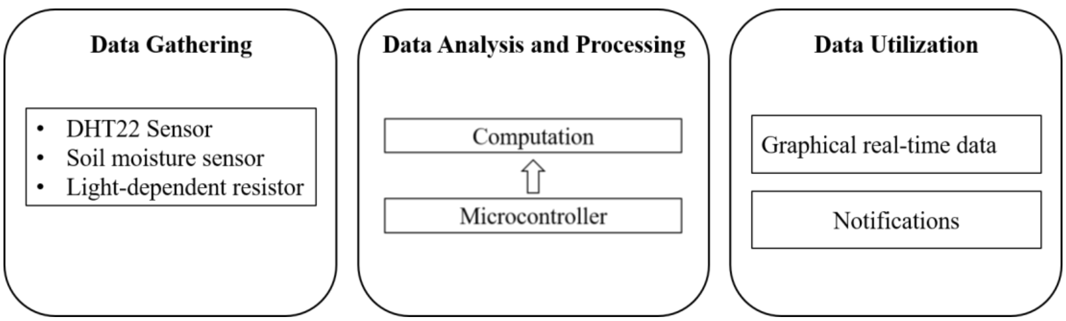

Figure 3.1. Smart greenhouse monitoring and maintenance system conceptual framework diagram

Block Diagram

The system is an application of feedback or closed-loop control system. Closed-loop system compensates for disturbances by measuring the output response, feeding that measurement back through a feedback path, and comparing that response to the input at the summing junction.[11] If there is any difference between the two responses, the system drives the plant, via the actuating signal, to make a correction. Figure 3.2 shows the closed-loop system block diagram for controlling the temperature and humidity of the greenhouse, where the fan speed changes according to the desired temperature and humidity inside the glasshouse. In Figure 3.3, the soil moisture sensor provides the compensation for providing water in which the soil of the plants is saturated. As a result, the drip irrigator will be either opened in order to provide irrigation or closed to stop watering the plants. On the other hand, the installed lights inside the house will provide lighting that will complement the light intensity absorbed by the sensor. Its working diagram is depicted in Figure 3.4.

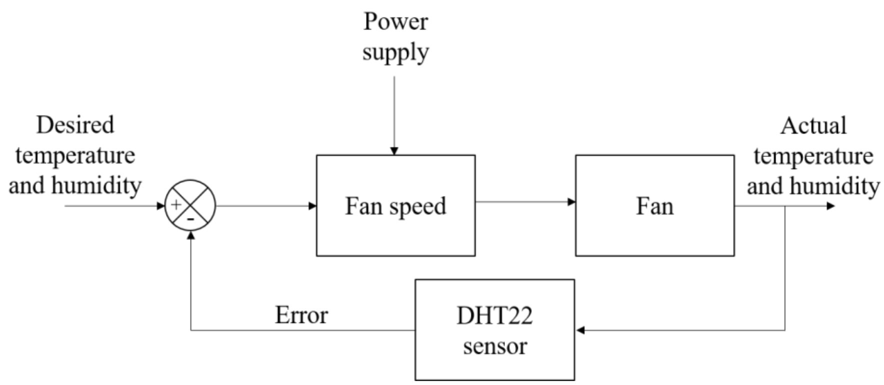

Figure 3.2. Temperature and humidity control

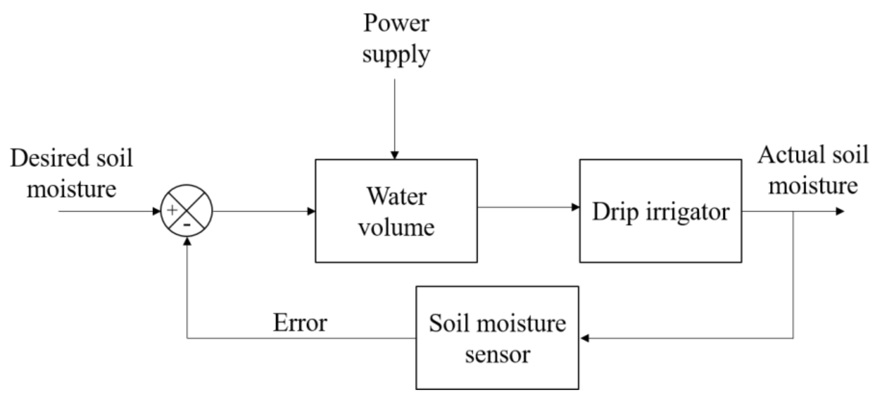

Figure 3.3. Soil moisture control

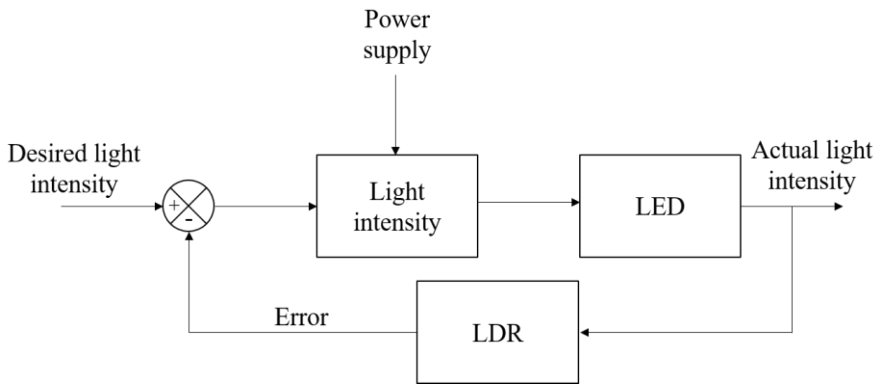

Figure 3.4. Light intensity control

Comprehensive Flowchart

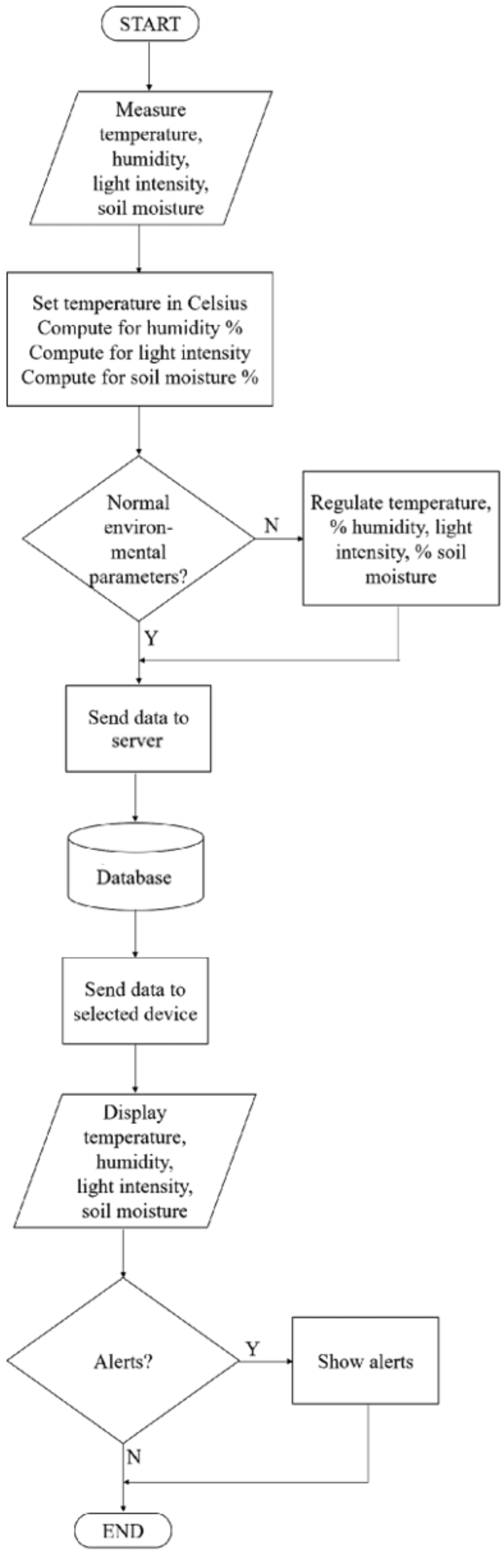

Figure 3.5. Smart greenhouse monitoring and maintenance system flowchart

Figure 3.5 shows the comprehensive flowchart of the system. The sensors acquire raw data and the microcontroller is programmed to convert raw data into useful information such as temperature in Celsius, humidity percentage, light intensity, and soil moisture percentage. Data are sent to the database and can be accessed in a graphical user interface. The system will provide notifications in case of abnormal conditions such as high increase or decrease in temperature, humidity, light intensity, and soil moisture.

Hardware Assembly and Implementation

Materials

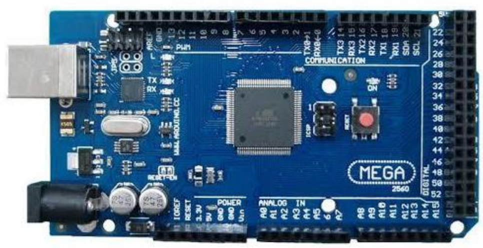

Figure 3.6. Arduino Mega 2560

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins of which 15 can be used as PWM outputs, 16 analog inputs, 4 UARTs or hardware serial ports, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It must be connected to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Arduino Mega 2560 is shown in Figure 3.6.[12]

Figure 3.7. DHT-22 temperature and humidity sensor

The DHT-22 is a digital-output relative humidity and temperature sensor. It uses a capacitive humidity sensor as well as a thermistor to measure the surrounding air and spits out a digital signal on the data pin. The first pin on the left is to 3.3-5V power supply, the second pin to data input pin, and the rightmost pin to the ground. It can carry current up to 2.5mA, provide humidity percentage ranging from 0-100% with 2-5% accuracy, and temperature range from 40°C to 80°C with ±0.5°C precision. This sensor is shown in Figure 3.7.[13]

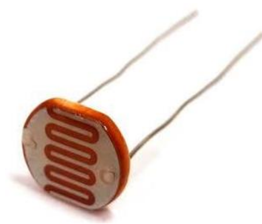

Figure 3.8. Light-dependent resistor

A photoresistor or light dependent resistor is a component that is sensitive to light. When light falls upon it, then the resistance changes. Values of the resistance of the LDR may change over many orders of magnitude the value of the resistance falling as the level of light increases. It is not uncommon for the values of resistance of an LDR or photoresistor to be several megohms in darkness and then to fall to a few hundred ohms in bright light. The sensitivity of light dependent resistors or photoresistors, as shown in Figure 3.8, also varies with the wavelength of the incident light.[14]

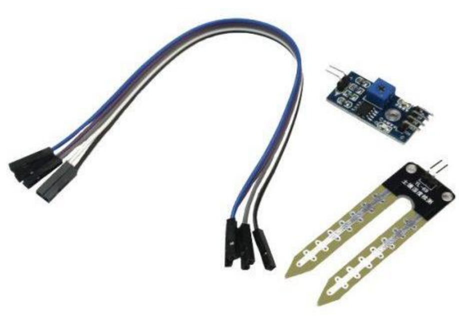

Figure 3.9. Soil moisture sensor module

The soil moisture sensor module in Figure 3.9 can be inserted into the soil and then adjust the on-board potentiometer to adjust the sensitivity. The sensor would output logic HIGH or LOW when the moisture is higher or lower than the threshold set by the potentiometer respectively. The plate is made of nickel plating to avoid corrosion, has working voltage or 3.3V-5V, and has an on-board LM393 chip.[15]

Figure 3.10. Submersible pump

The submersible pump shown in Figure 3.10 lifts the water from the water supply in order to provide irrigation to the plants. It can carry 3-5V and can lift in the 40-110cm range. Its flow rate ranges from 80 to 120 L/H and its driving mode consists of brushless DC design and magnetic driving.[16] It is recommended to use a pump with a higher power or PSI if the prototype will be scaled larger than the prototype.

Software Application

1. Arduino IDE

   The Arduino IDE is an Integrated Development Environment that runs on the computer and is used to write and upload computer code to the physical board.

2. Processing 3

   Processing is a flexible software sketchbook and a language for learning how to code within the context of the visual arts.

Mathematical Models

In this section, mathematical computations of the environmental parameters are discussed. The formulas and standard values are retrieved from trusted libraries that use concepts related to ambient monitoring.

1. Temperature and Humidity

Currently, there is an Arduino library for the DHT series of low-cost temperature/humidity sensors. DHT sensor library is compatible with multiple low-cost temperature and humidity sensors like DHT11 and DHT22. A few examples are implemented just to demonstrate how to modify the code for different sensors.

```
#include <DHT.h>
#define DHTPIN 12
#define DHTTYPE DHT22
DHT dht(DHTPIN, DHTTYPE);

float hum;  //Stores humidity value
float temp; //Stores temperature value

void setup()
{
  Serial.begin(9600);
  dht.begin();
}
void loop()
{
  // Compute and display temperature and humidity
  hum  = dht.readHumidity();
  temp = dht.readTemperature();
  Serial.print("*H: ");
  Serial.print(hum);
```

```
  Serial.print("%, T: ");
  Serial.print(temp);
}
```

2. Light intensity

The LDR is a special type of resistor that allows higher voltages to pass through it whenever there is a high intensity of light and passes a low voltage whenever it is dark.

```
#define ldrPin A1
void setup()
{
  Serial.begin(9600);
}
void loop()
{
  int newLDRPin = map(analogRead(ldrPin), 0, 1023, 0, 99);
  Serial.print("*LDR: ");
  Serial.println(newLDRPin);
}
```

3. Soil moisture

The Soil Moisture Sensor measures soil moisture grace to the changes in electrical conductivity of the earth as soil resistance increases with drought.

```
#define soilPin A2
{
  Serial.begin(9600);
}
void loop()
```

```
{
  float soilMoisture = (((analogRead(soilPin))/1023.00)*100);
  Serial.print("*Moist: ");
  Serial.print(soilMoisture);
  Serial.println("%");
}
```

Results and Discussion

This section provides the analysis and interpretation from the results gathered from sets of testing conducted by the proponents.

1. Temperature

The ideal temperature inside the greenhouse is from 26.7 to 29.4 degrees Celsius. Raw temperature data produced by manual gathering of data and from DHT-22 sensor. Table 3.1 shows the experimental and theoretical measurement of temperature in the greenhouse and the percentage error.

Table 3.1. DHT-22 sensor accuracy test

Trial*	**Temperature (°C) using Digital Thermometer**	**Temperature (°C) using DHT-22 sensor**
1	27.6	27.9
2	27.8	28
3	28.2	28.1
Average Temperature	27.87	28
% Difference	0.005%	

*observed in an interval of five minutes

2. Light intensity

   The pin in which the light-dependent resistor is connected provides a value that ranges from 0-99. When the LDR is not covered, it generates values from 82-99. Otherwise, it generated values from 10-75. Thus, 80 is set as the threshold for triggering the light. The lights in the greenhouse provide adequate lighting for the plants inside the glasshouse.

3. Soil moisture

   The pin in which the soil moisture sensor is connected provides a value that ranges from 0%-100%. At dry conditions, the sensor reads <10% of soil moisture. Under wet soil conditions, it generates a reading that ranges from 50%-80%. When the soil moisture is at 40%, the pump opens and provides water drip to the plants.

CHAPTER 4

CONCLUSION

The Smart Greenhouse Monitoring and Maintenance System is an autonomous, closed-loop control system that regulates environmental parameters in a greenhouse used as an urban farming market. The system was able to read temperature, humidity, light intensity, and soil moisture through the sensors. Device readings were provided in a graphical format to allow the grower to view the current status of the greenhouse. The temperature in Celsius, humidity and moisture percentage, as well as light intensity are displayed.

The proponents constructed a greenhouse with an application of closed-loop control system that monitors and controls the environmental parameters of a greenhouse. The system automates the ventilation system that is controlled depending on the sensor values of humidity and temperature, provides an automated lighting system on the greenhouse to sustain the health of the plants, and enables drip irrigation without manual intervention.

The system performs the following as expected: an automated ventilation system that is controlled depending on the sensor values of humidity and temperature; an automated lighting system that is controlled depending on the sensor values of light intensity; and an automated irrigation system that is controlled depending on the sensor values of soil moisture.

The system provides a graphical user interface for representation of real-time temperature, humidity, light intensity, and soil moisture data. The temperature in Celsius, humidity and moisture percentage, as well as light intensity are displayed and can be viewed by the user.

Finally, notifications regarding with the overall condition of the greenhouse is also provided by the system. This pertinent information is based on the acquired temperature, humidity, and soil moisture values inside the greenhouse. As a result, the system can be utilized for urban farming markets that can be installed in urban residences such as condominiums and apartments.

CHAPTER 5

RECOMMENDATIONS

The proponents of this study propose to include measuring and regulating intermediate environmental parameters such as carbon dioxide, pH level of soil, and amount of water consumed due to irrigation. Enhancements with the graphical user interface displaying real-time is suggested for future work. On the other hand, utilization of an independent, solar voltage source as well as rainwater harvesting is recommended. Also, upon integration on an actual urban market setup, it is recommended that all vegetables of the same type and requirements stay together in the same greenhouse, additionally, it should be noted that these plants must be able to thrive together considering different factors stated in this research.

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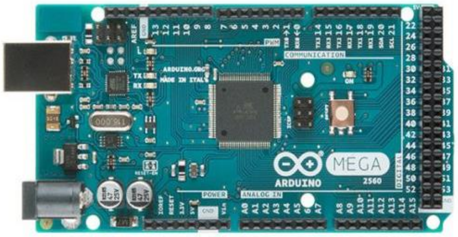
APPENDICES

Hardware Specifications

Arduino Mega 2560 R3 Italy Genuine



As title suggest the Arduino Mega 2560 R3 Italy Genuine is the Genuine/ Original Board made from Italy, and not a clone which are usually made in China, though it is more expensive compared to the clones, the board is more robust and will last longer compared to a clone.

The Arduino Mega is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

The Mega 2560 R3 also adds SDA and SCL pins next to the AREF. In addition, there are two new pins placed near the RESET pin. One is the IOREF that allow the shields to adapt to the voltage provided from the board. The other is a not connected and is reserved for future purposes. The Mega 2560 R3 works with all existing shields but can adapt to new shields which use these additional pins.

Features:

- ATmega2560 microcontroller

- Input voltage – 7-12V
- 54 Digital I/O Pins (14 PWM outputs)
- 16 Analog Inputs
- 256k Flash Memory
- 16Mhz Clock Speed

DHT-22 Temperature and Humidity Sensor Module

The DHT22 Temperature and Humidity Sensor is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and outputs a digital signal on the data pin. It's fairly simple to use, but requires careful timing to grab data. The only real downside of this sensor is you can only get new data from it once every 2 seconds, so when using our library, sensor readings can be up to 2 seconds old.

Simply connect the first pin on the left to 3-5V power, the second pin to your data input pin and the right most pin to ground. Although it uses a single-wire to send data it is not Dallas One Wire compatible! If you want multiple sensors, each one must have its own data pin! We have written an Arduino library with example code

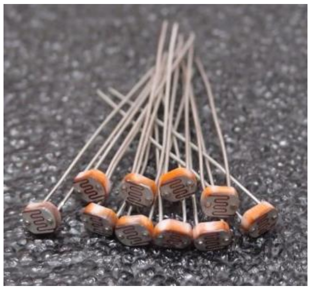
Compared to the DHT11, this sensor is more precise, more accurate and works in a bigger range of temperature/humidity, but its larger and more expensive

Comes with a 4.7K – 10K resistor, which you will want to use as a pullup from the data pin to VCC.

TECHNICAL DETAILS

- 3 to 5V power and I/O
- 5mA max current use during conversion (while requesting data)
- Good for 0-100% humidity readings with 2-5% accuracy
- Good for -40 to 80°C temperature readings ±0.5°C accuracy
- No more than 0.5 Hz sampling rate (once every 2 seconds)
- Body size 27mm x 59mm x 13.5mm (1.05″ x 2.32″ x 0.53″)
- 4 pins, 0.1″ spacing
- Weight (just the DHT22): 2.4g

Light-Dependent Resistor



This Light Dependent Resistor is a very small light sensor. A photocell changes (also called a photodetector, photo resistor, CdS or photoconductive cell) resistance depending on the amount of light it is exposed to. These little sensors make great ambient light triggers (when light in the room turns on, do something).

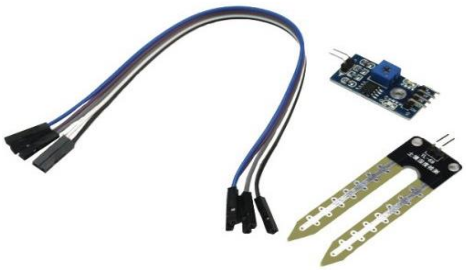
Features:

- Light resistance : ~1k Ohm
- Dark resistance : ~10k Ohm
- Max voltage : 150V
- Max power: 100mW

Dimensions:

- 2 x 4 x 5mm
- 4mm between pins
- 31mm lead length

Soil Moisture Sensor Module



This Soil Moisture Sensor Module can be used to detect the moisture of soil or judge if there is water around the sensor, let the plants in your garden reach out for human help. Insert this module into the soil and then adjust the on-board potentiometer to adjust the sensitivity. The sensor would output logic HIGH/LOW when the moisture is higher/lower than the threshold set by the potentiometer. With help of this sensor, it will be realizable to make the plant remind you : Hey, I am thirsty now, please give me some water.

Features:

Digital output, easy to adjust

Nickel plating to avoid corrosion

Working voltage: 3.3V-5V

On-board LM393 chip

Dimension of the board: 3.2cm * 1.4cm

Submersible Pump

This Mini Submersible Pump 3-5V is great for experiment, aquarium, and fountain etc. It is suitable for varieties of water such as city water, ground water and sea water.

Specification:

DC Voltage: 3-5V

Low Noise

Maximum Lift: 40-110cm / 15.75″-43.4″

Flow rate:80-120L/H

Outside diameter of water outlet: 7.5mm / 0.3″

Inside diameter of water outlet: 4.7mm / 0.18″

Diameter: Approx. 24mm / 0.95″Length:Approx. 45mm / 1.8″

Height: Approx. 33mm / 1.30″

Material: engineering plastic

Driving mode: brushless dc design, magnetic driving

Continuous working life of 500 hours

Source Code

Arduino

```
#include <DHT.h>

#define DHTPIN 12
#define DHTTYPE DHT22
DHT dht(DHTPIN, DHTTYPE);
#define ldrPin A1 // red led
#define soilPin A2 //blue resistor

#define pwmFan A0
#define ledPin 3
#define pumpPin 5 // regular resistor

void setup()
{
  Serial.begin(9600);
  dht.begin();
  pinMode(pwmFan,OUTPUT);
  pinMode(ledPin, OUTPUT);
  pinMode(pumpPin, OUTPUT);
}

void loop()
{
  float hum  = dht.readHumidity();
  float temp = dht.readTemperature();
  Serial.print(temp);
  Serial.print(",");
  Serial.print(hum);

  int light = map(analogRead(ldrPin), 0,
1023, 0, 99);
  Serial.print(",");
  Serial.print(light);

  float soilMoisture =
(((analogRead(soilPin))/1023.00)*100);
  Serial.print(",");
  Serial.println(soilMoisture);

  if(temp>=24.4 && hum<=80)
```

```
    analogWrite(pwmFan,224);
  else
    analogWrite(pwmFan,0);

  if (newLDRPin <= 70)
    digitalWrite(ledPin, HIGH);
  else
    digitalWrite(ledPin, LOW);

  if (soilMoisture <= 40)
    analogWrite(pumpPin, 255);
  else
    analogWrite(pumpPin, 0);

  delay(1000);
}
```

Processing 3

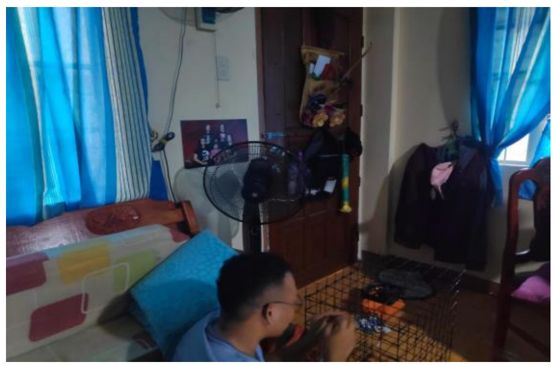
```
import meter.*;
import processing.serial.*;

Serial port;
Meter m, m2, m3, m4;

  int value3 = 0;
  int value4 = 0;

void setup()
{
  size(940, 650);
  background(20, 20, 20);

//  port = new Serial(this, "COM5", 9600);

  // TEMPERATURE METER
  m = new Meter(this, 18, 38);
  m.setTitleFontSize(16);
  m.setTitleFontName("Arial");
  m.setTitle("Temperature (°C)");
  String[] scaleLabels = {"0","10", "20", "30", "40"};
  m.setScaleLabels(scaleLabels);
  m.setScaleFontSize(16);
  m.setScaleFontName("Times New Roman");
```

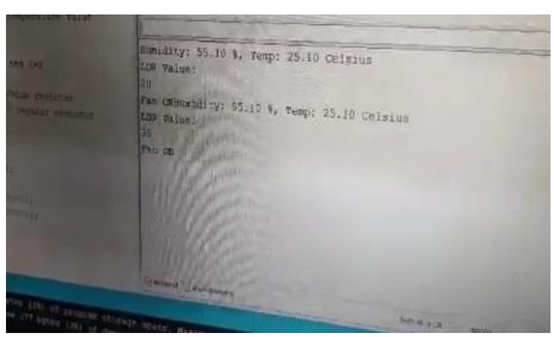
```
m.setScaleFontColor(color(200,30,70));

m.setDisplayDigitalMeterValue(true);

m.setArcColor(color(141,113,178));

m.setArcThickness(15);

m.setMaxScaleValue(40);

m.setMinInputSignal(0);

m.setMaxInputSignal(40);

m.setNeedleThickness(3);


// HUMIDITY METER

int mx = m.getMeterX();

int my = m.getMeterY();

int mw = m.getMeterWidth();

m2 = new Meter(this, mx+mw+20,my);

m2.setTitleFontSize(16);

m2.setTitleFontName("Arial");

m2.setTitle("Humidity (%)");

String[] scaleLabels2 =
{"0","10","20","30","40","50","60","70","80
","90","100"};

m2.setScaleLabels(scaleLabels2);

m2.setScaleFontSize(16);

m2.setScaleFontName("Times New
Roman");

m2.setScaleFontColor(color(200,30,70));

m2.setDisplayDigitalMeterValue(true);

m2.setArcColor(color(141,113,178));

m2.setArcThickness(15);

m2.setMaxScaleValue(100);

m2.setMinInputSignal(0);

m2.setMaxInputSignal(100);

m2.setNeedleThickness(3);


// LIGHT

m3 = new Meter(this, mx,my+320);

m3.setTitleFontSize(16);

m3.setTitleFontName("Arial");

m3.setTitle("Light");

String[] scaleLabels3 =
{"0","10","20","30","40","50","60","70","80
","90","100"};

m3.setScaleLabels(scaleLabels3);

m3.setDisplayDigitalMeterValue(true);

m3.setArcColor(color(141,113,178));

m3.setArcThickness(15);
```

```
  m3.setMaxScaleValue(100);

  m3.setMinInputSignal(0);

  m3.setMaxInputSignal(100);

  m3.setNeedleThickness(3);


  // SOIL MOISTURE

  int mx2 = m3.getMeterX();

  int my2 = m3.getMeterY();

  int mw2 = m3.getMeterWidth();

  m4 = new Meter(this, mx2+mw2+20,my2);

  m4.setTitleFontSize(16);

  m4.setTitleFontName("Arial");

  m4.setTitle("Soil Moisture");

  String[] scaleLabels4 =
{"0","10","20","30","40","50","60","70","80
","90","100"};

  m4.setScaleLabels(scaleLabels4);

  m4.setDisplayDigitalMeterValue(true);

  m4.setArcColor(color(141,113,178));

  m4.setArcThickness(15);

  m4.setMaxScaleValue(100);

  m4.setMinInputSignal(0);

  m4.setMaxInputSignal(100);

  m4.setNeedleThickness(3);

}


void draw(){

  background(0);


  if(port.available()>0)

  {

    String val = port.readString();

    String[] list = split(val,',');


    float temp = float(list[0]);

    float hum = float(list[1]);

    float light = float(list[2]);

    float soil = float(list[3]);


    m.updateMeter(int(temp));

    m2.updateMeter(int(hum));

    m3.updateMeter(int(light));

    m4.updateMeter(int(soil));


    String dark = "Light intensity | LED
Status: ON";
```

```
    String bright = "Light intensity | LED
Status: OFF";
    if (light <= 70)
      text(dark, 80,350);
     else
      text(bright, 80,350);


    String wet = "Soil moisture | Pump Status:
ON";
    String bright = "Soil moisture | Pump
Status: OFF";
    if (soil <= 40)
      text(dark, 540,350);
     else
      text(bright, 540,350);


    println(temp + "," + hum + "," + light +
"," + soil);
  }
```

Construction and Experimentation





Video Pitch Transcript

Urbanization in the Philippines has risen by 5.9% from 2010 to 2015. Urban landscaping through greenhouse construction offers visual beauty and relief and delivers ambient cooling benefits. Plants filter pollutants through photosynthesis and biofiltration, helps reduce risks of various diseases, and may provide sources of food for human consumption. However, maintaining greenhouse in busy cities is a challenge that must be fulfilled. If there is an autonomous system that delivers the basic needs of the plants, the grower will save in terms of costs, and plants will remain healthy.

The Smart Greenhouse Monitoring and Maintenance System for Productive Urban Farming Markets monitors and controls the environmental parameters of a greenhouse on a regular basis. The system comprises of various sensors and actuators that will measure and regulate temperature, humidity, light, and soil moisture inside the greenhouse. The set-up will be equipped with a low-cost and effective microcontroller which will perform the overall processing of the system. The plants that will be planted are edible plants, thus making the greenhouse equivalent to an urban farming market. The system also includes a mobile application which can be accessed via the Internet. It displays real-time data obtained from the sensors in graphical format and alerts the user about the condition of the greenhouse. As a result, unattended monitoring due to time constraints is eliminated and food production in the urban farm setup is optimized.

Its potential benefit is to maximize urban spaces for urban markets, as well as turn parts of it for green spaces. Also, to motivate residents of urbanized areas such as condominiums and apartments to grow their own produce and ensure they are organically grown and freshly harvested for their own consumption and in turn, inspire them to participate in uprising urban markets in society's efforts for sustainable living and development.

PROPONENT'S PROFILE

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