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Implementation of an Automated System for Controlling and Monitoring a Hydroponic Greenhouse

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Abstract: *The objective of the paper is to create a hydroponic domestic controller that monitors and controls the environmental factors necessary for a successful hydroponic culture. The implementation was held using the Arduino Mega 2560 platform as it has a lot of memory and provides several slots to support screens, sensors, relays and shields. The system gathers data relating to light intensity of the light bulb, humidity and temperature of the greenhouse, temperature, level, conductivity and acidity of the crop mixture and sends them to the Arduino microcontroller. The user via an LCD monitor is able to monitor the above data in real time and manually control the activation and deactivation of the ventilation, fan, lamp, and humidifier of the greenhouse. In addition, he/she is able to define the lowest desired humidity limit, the acidity limits of the mixture, the fertilizers dosings as well as the exact time of activation and deactivation of the culture lamp. The controller undertakes to manage all of the above data and automatically perform specific functions to maintain the cultivation factors related to lamp's operation time, plant nutrition, crop acidity, and room humidity at the desired levels. The controller also provides the ability to store and monitor the maximum and minimum values of environmental factors that occur during operation.*

Keywords -*Hydroponic Domestic Controller, Arduino Mega, Cultivation Factors*

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I. Introduction

In recent years, a shift to urban agriculture and domestic hydroponic farming has been observed in many European and not only countries. Hydroponics is an excellent technique for such efforts because it provides high quality crops in short periods of time but also in small spaces due to the absence of soil.

This paper focuses on the creation of a system for monitoring and controlling a hydroponic greenhouse. The aim is to give the modern city man an opportunity to grow small quantities of fruit, vegetables and herbs with little financial and time cost.

The controller can be used on larger-scale crops inside or outside a greenhouse with small conversions. At present it is suitable for hydroponic crops in a specially designed greenhouse using a lamp that mimics the sunlight.

For the correct and rapid growth of plants, it is necessary to maintain environmental factors at the correct and permissible levels. More specifically, the controller collects the values of the environmental factors and automatically adjusts to the desired levels the humidity of the growing area, the acidity of the culture water as well as the operation time of the culture lamp. In addition, user is able to select the desired fertilizer dosages and these are automatically injected into the tank with the touch of a button. The controller also offers the ability to manually activate and deactivate lighting, ventilation, fan and humidifier.

The creation of an inexpensive and open source hydroponic controller gives the motivation of cultivation to everyone since all processes are simpler, faster and more reliable even in houses

II. Problem Formulation

Monitoring and controlling the environmental factors of a hydroponic culture are two important processes for securing a successful crop. In nowadays, hydroponic controllers are costly and usually deal exclusively with controlling the crop mix ignoring the control of the greenhouse climate. The present controller has been created to circumvent the above problems offering simultaneous climate and mix control at a reasonable cost.

III. Proposed System

The key member of the control system is the Arduino Mega 2560 on which a number of peripheral components and sensors are connected. The microcontroller, after collecting the necessary data from the sensors, performs the appropriate actions either automatically or at the command of the user.

3.1. MEASUREMENTS MONITORING

The key member of the control system is the Arduino Mega 2560 on which a number of peripheral components and sensors are connected. The microcontroller, after collecting the necessary data from the sensors, performs the appropriate actions either automatically or at the command of the user.

3.1.1 Arduino Mega 2560

Arduino Mega 2560 was chosen to be the heart of the hydroponic controller. It uses the processing power of the ATmega2560 microchip and has 54 digital inputs / outputs and 12 analogue inputs making it ideal for fitting the components of the proposed control system. It can be powered via USB or external power supply. In addition, Arduino Mega has 250 KB of free space for software storage (code) and 4 KB of free space for data storage (EEPROM) [1].

Figure 1: Arduino Mega 2560

3.1.2. Microbot LCD Shield

LCD Shield fits just above the Arduino Mega 2560 allowing the microcontroller to visualize informations. In addition, five push buttons make possible the implementation of projects where the menus appear on the screen and the options are made by the pressure of the buttons [2].

Figure 2: Microbot LCD shield

3.1.3. DHT 11 Sensor

DHT sensor 11 was selected to measure the temperature and humidity of the culture area. It is very easy to use but requires great attention to sampling frequency as it should be greater than 2 seconds. This particularity does not create problems because there are no great fluctuations of temperature and humidity in growing areas [3].

Figure 3:DHT 11 sensor

3.1.4. DS18B20 Sensor

The waterproof version of the DS18B20 sensor was selected to measure the temperature of the culture water. It provides temperature measurements in Celsius and communicates with the microcontroller via the 1-wire bus protocol. It is covered with a plastic housing so it can be immersed into the water and has a 3 m long cable that gives flexibility to the entire construction [4].

Figure 4:DS18B20 sensor

3.1.5. HC-SR04 Sensor

The HC-SR04 sensor was selected to measure the water level in the cultivation tank. It uses ultrasound to calculate the distance from a body by mimicking the technique of bats and dolphins. An ultrasonic pulse emitted by the sensor impinges on the free surface of the water and returns. The distance between them is determined by measuring the time required for the echo return [5].

Figure 5:HC-SR04 Sensor

3.1.6. Tiny RTC I2C

The RTC I2C module was used to preserve the date and time of the hydroponic controller even if it is deactivated. Its function is based on the DS1307 chip which supports the I2C protocol and is powered by a lithium battery(CR1225) [6].

Figure 6: Tiny RTC I2C

3.1.7. Photocell

A simple photocell was used to measure the intensity of the light for checking the ON-OFF status of the cultivation lamp. Essentially photocell is a variable resistance whose value changes depending on the light that falls on it [7].

Figure 7: Photocell

3.1.8. Acidity Sensor (pH)

The analogue, low-cost acidity sensor of Df Robot was used to measure the acidity of the nutrient solution.It is specially designed to work with Arduino microcontrollers and has its own circuit that connects the sensor to the microcontroller [8].

Figure 8: Acidity Sensor (pH)

3.1.9. Conductivity Sensor (EC)

In order to measure the electrical conductivity of the nutrient solution, no trade sensors were selected due to high cost and thus the diy (do it yourself) option was followed. The constructed sensor is an idea of Michael Ractliffe, consists of a European-type socket, a 500 ohm resistor, a DS18B20 waterproof sensor (already used in the project) and costs only 4 € [9].

3.1.10. Light Emitting Diode (LED)

For visualization of the alarms in addition to the lcd screen, 2 LEDs were also used. LEDs are semiconductors which emit narrow-range light radiation when supplied with an electric voltage in a forward-biased direction. The red led is triggered when a high value is detected in one of the measured quantities while the yellow led is triggered when a low value is detected in one of the measured quantities [10].

3.2. MANUAL OPERATIONS

The user through the controller is able to activate and deactivate on his/her own initiative the lamp, fan, ventilation and humidifier of the greenhouse. He/She has also the ability to activate the automatic fertilizer dosing function after first choosing the desired dosages. The functionality of relay, lamp, fan, vent, humidifier and peristaltic pumps is described below, while the functionality of the parts of chapter 3 remains the same.

3.2.2. Channel Relay Module

To control lighting, humidifier, fan, ventilation and 4 metering pumps, an 8-channel board with built-in relays was used. Each of the above controlled devices is individually connected to the respective relay. When a relay is activated, it also closes the corresponding circuit by switching on the corresponding device [11].

Figure 9:8 channel relay module

3.2.3. Cultivation Lamp

Photosynthesis is a necessary biological process for the proper growth of a plant. More specifically, it is the process in which green plants and some other organisms transform light energy into chemical.

Therefore, the key feature of a successful greenhouse crop in enclosed spaces is the cultivation lamps. They are designed for indoor plant cultivation by producing high light output. Many types of bulbs are available in the market such as HPS, Metal Halide, CFL, LED, PL, Lux Meters [12].

3.2.4. Ventilation

For the optimum supply of fresh air to the cultivation chamber it is necessary to use a vent unit.Appropriate units for domestic use must have fire protection, robust performance and small size.

Figure 10: Ventilation

3.2.5. Fan

For the correct air circulation in the growing chamber it is necessary to use a fan. Appropriate units for domestic use must have fire protection, strong performance and relatively small size.

3.2.6. Ultrasonic Humidifier

An ultrasonic humidifier was selected to humidify the culture area. It has a small metal plate that vibrates at an ultrasonic frequency and converts the liquid in which the humidifier is immersed into steam [13].

Figure 11: Ultrasonic humidifier

3.2.7. Peristaltic Pumps

Four peristaltic pumps were selected to transfer the nutrient and buffer solutions from the containers to the cultivation tank. Unlike most liquid pumps, this type squishes the silicone tubing that contains the liquid instead of pushing the liquid itself in one direction. In this way the pump never touches the fluid making it the ideal solution for pumping food or sterile liquids [14].

Figure 12: Peristaltic pump

3.3. Automatic Operations

The algorithms of the hydroponic controller are capable to automatically maintain the moisture of the growing area and the acidity of the crop mixture to the desired levels chosen by the user. In addition, controller is equipped with a timer to activate and deactivate the bulb at certain times selected also by the user.

In particular, the system every ten seconds measures the humidity of the growing area. If the humidity value is lower than the one selected by the user as lower then, the humidifier is activated for ten seconds. Right after it is deactivated for ten seconds and if the humidity value is still below the desired level, it will be re-activated. This process is repeated until the value of the humidity exceeds the lower desired user limit.

With regard to automatic adjustment of acidity, the controller measures the acidity of the crop mix at intervals selected by the user. If the value of the acidity is higher than the one selected by the user as maximum, the controller transfers the appropriate buffer fluid to the tank to reduce the acidity. The amount of buffer fluid is selected by the user. The same mechanism is triggered if the controller realizes that the value of the acidity has fallen below the desired level. The process is repeated until the acidity value of the mixture equilibrates between the desired values.

Automations are performed with the help of the appropriate components and sensors discussed in sections 3.1 and 3.2.

IV. Operations Software

4.1. Algorithm for Manual Activation /Deactivation of the cultivation lamp

Inputs:
- pValue; Photocell value.

Outputs:
- digitalWrite(RELAY1PIN, LOW); If the bulb is off.
- digitalWrite(RELAY1PIN, HIGH); If the bulb is on.

Algorithm:
1. Start
2. Read pValue from sensor
3. If pValue < 20

then digitalWrite(RELAY1PIN, LOW)

else digitalWrite(RELAY1PIN, HIGH)
4. End.

4.2. ALGORITHM FOR MANUAL ACTIVATION /DEACTIVATION OF THE HUMIDIFIER

Inputs:
- digitalRead(RELAY2PIN); Pin state

Outputs:
- digitalWrite(RELAY2PIN, LOW); If the humidifier is off.
- digitalWrite(RELAY2PIN, HIGH); If the humidifier is on.

Algorithm:
1. Start
2. Read pin state(0/1)
3. If digitalRead(RELAY2PIN) == LOW

then digitalWrite(RELAY2PIN, HIGH)
else digitalWrite(RELAY2PIN, LOW)
4. End

The algorithms concerning the manual activation / deactivation of ventilation and fan are executed in exactly the same way.

4.3. ALGORITHM FOR AUTOMATIC ACTIVATION /DEACTIVATION OF THE CULTIVATION LAMP

The algorithms of the hydroponic controller are capable to automatically maintain the moisture of the growing area and the acidity of the crop mixture to the desired levels chosen by the user. In addition, controller is equipped with a timer to activate and deactivate the bulb at certain times selected also by the user.

Inputs:
- onHour; Lamp activation hour.
- onMinute; Lamp activation minutes.
- offHour; Lamp deactivation hour.
- offMinute; Lamp deactivation minutes.
- hourValue; Present hour.
- minuteValue; Present minutes.
- secondValue; Present seconds.

Outputs:
- digitalWrite(RELAY1PIN, LOW); If present hour and minutes are equal with activation hour and minutes.
- digitalWrite(RELAY1PIN, HIGH); If present hour and minutes are equal with deactivation hour and minutes.

Algorithm:
1. Start
2. Read present hour, minutes, seconds
3. If ((hourValue == onHour)

and (minuteValue == onMinute)
and (secondValue == 15))
then digitalWrite(RELAY1PIN, LOW);
4. If ((hourValue == offHour)
and (minuteValue == offMinute)
and (secondValue == 15))
then digitalWrite(RELAY1PIN, HIGH);
4. End

4.4. ALGORITHM FOR AUTOMATIC ACTIVATION /DEACTIVATION OF THE HUMIDIFIER

Inputs:
- humidifierSP; Lower humidity level.
- timeElapsedAutoHumidifier; Counter.
- timeElapsedAutoHumidifier1; Counter.
- humidityValue; Humidity value detected by sensor

Outputs:
- digitalWrite(RELAY2PIN, LOW); If the humidity level is below the desired level.
- digitalWrite(RELAY2PIN, HIGH); If the humidity level is above the desired level.

Algorithm:

1. Start
2. If timeElapsedAutoHumidifier > 10000 then
3. Read humidity value from sensor
4. If humidityValue < humidifierSP then
5. If timeElapsedAutoHumidifier1 > 12000

then digitalWrite(RELAY2PIN, LOW);
    timeElapsedAutoHumidifier1 = 0 ;
else digitalWrite(RELAY2PIN, HIGH);

6. Else digitalWrite(RELAY2PIN,HIGH);
7. End.

4.5. ALGORITHM FOR AUTOMATIC ACIDITY ADJUSTMENT

Inputs:

- phAutoDose; Duration of pump activation
- maxPhSP; Maximum acidity level.
- minPhSP; Minimum acidity level.
- timeElapsedAutoPh; Counter
- timeElapsedAutoPhCorrector: Counter
- phFinish: Final Acidity Value from Sensor
- phStart: Initial acidity value from sensor
- phData: Read acidity value from sensor
- phFr: Dosage frequency

Outputs:

- digitalWrite(RELAY7PIN, LOW); If the acidity level is below the desired level.
- digitalWrite(RELAY8PIN, LOW); If the acidity level is above the desired level.

Algorithm:

1. Start
2. phAutoCounter = phAutoDose*1000;
3. If timeElapsedAutoPh> phAutoCounter then
4. digitalWrite(RELAY7PIN, HIGH);
5. digitalWrite(RELAY8PIN, HIGH);
6. If timeElapsedAutoPhCorrector> 12000 then
7. Read final acidity value from sensor
8. Absolute difference between final and initial acidity value(absDiff).
9. If absDiff <= 0.01 then
10. If timeElapsedAutoPhCorrector1> phFr then
11. Read acidity value from sensor
12. If phData < minPhSp

then digitalWrite(RELAY7PIN, LOW);
else digitalWrite(RELAY7PIN, HIGH);

13. If phData > maxPhSp

then digitalWrite(RELAY8PIN, LOW);
else digitalWrite(RELAY8PIN, HIGH);

14. timeElapsedAutoPhCorrector1 = 0;
15. Read initial acidity value
16. timeElapsedAutoPhCorrector = 0;
17. timeElapsedAutoPh = 0;

4.6. ALGORITHM FOR AUTOMATIC DOSAGE

Inputs:

- nut1; Duration of pump1 activation.
- nut2; Duration of pump2 activation.
- nut3; Duration of pump3 activation.
- nut4; Duration of pump4 activation
- timeElapsedNutrients: Counter

Outputs:

- digitalWrite(RELAY4PIN, LOW); If this solution is selected.
- digitalWrite(RELAY6PIN, LOW); If this solution is selected.
- digitalWrite(RELAY7PIN, LOW); If this solution is selected.
- digitalWrite(RELAY8PIN, LOW); If this solution is selected.

Algorithm:
1. Start
2. highCounter1 = nut1*1000;
3. highCounter2 = lowCounter1+(nut2*1000);
4. highCounter3 = lowCounter2+(nut3*1000);
5. highCounter4 = lowCounter3+(nut4*1000);
6. lowCounter1 = highCounter1+1000;
7. lowCounter2 = highCounter2+1000;
8. lowCounter3 = highCounter3+1000;
9. If timeElapsedNutrients< highCounter1 then digitalWrite(RELAY5PIN, LOW);
10. If (timeElapsedNutrients > highCounter1
and timeElapsedNutrients < lowCounter1) then digitalWrite(RELAY5PIN, HIGH);
11. If (timeElapsedNutrients > lowCounter1
and timeElapsedNutrients < highCounter2) then digitalWrite(RELAY6PIN, LOW);
12. If (timeElapsedNutrients > highCounter2
and timeElapsedNutrients < lowCounter2)
then digitalWrite(RELAY6PIN, HIGH);
13. If (timeElapsedNutrients > lowCounter2
and timeElapsedNutrients < highCounter3) then digitalWrite(RELAY7PIN, LOW);
14. If (timeElapsedNutrients > highCounter3
and timeElapsedNutrients < lowCounter3) then digitalWrite(RELAY7PIN, HIGH);
15. If (timeElapsedNutrients > lowCounter3
and timeElapsedNutrients < highCounter4) then digitalWrite(RELAY8PIN, LOW);
16. If timeElapsedNutrients > highCounter4
then digitalWrite(RELAY8PIN, HIGH);
17. timeElapsedNutrients=0;

V. Assembly

The cable connection of the hydroponic controller is shown in detail in Figure 13.

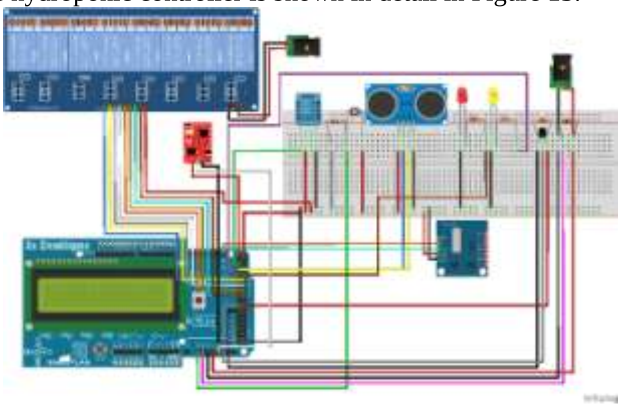

Figure 13: Controller's cable connection

VI. Future Improvements

Possible future improvements that can be applied to the hydroponic controller are the following:
1. Design and transfer of the circuit from breadboard to pcb.
2. Creation of a web application for handling and monitoring the hydroponic controller via computer, tablet and smart phone.
3. Replacement of lcd screen with touchscreen
4. Addition of more relays for using more nutrient liquids.
5. Supplying the pH sensor from external power for greater measurement accuracy.

VII. Conclusion

In this paper is proposed the construction of a hydroponic controller that is capable of maintaining the cultivation parameters at the ideal levels automatically or by user intervention.

The platform used is Arduino Mega as it has large storage space for software storage and many terminal locations to connect all peripheral components. The code for the graphic environment is completely separate from the code for automation and component handling, offering great flexibility in future modifications.

The controller offers a wide range of automation systems to greatly simplify the process of hydroponic cultivation saving the user valuable time and money. In addition, it helps to reduce the probability of a failed crop as the user has full control of the greenhouse. These facilities provide an incentive for anyone to engage in hydroponic farming and to come close to nature even in urban centers.

The simulating tests that performed have proven that the controller works according to anticipated expectations. At this stage it cannot be used for commercial purposes in large-scale greenhouses, but with targeted changes and modifications, this can be possible.

Finally, the usability test conducted by a user who did not have previous contact with the controller has come to the conclusion that manipulation via LCD screen is easy and simple.

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