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Fully Automated Hydroponic System for Indoor Plant Growth

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Abstract

Growing certain plants and vegetables in remote areas such as deserts and the north and south pole can be a challenge because of the extreme outside weather. Very few species of plants thrive in such situations and are often not used as a food source [1]. In this study, we created a system that can grow common plants and vegetables and can operate without depending on the outside climate. We achieved this by using a technique called Hydroponics. Hydroponics is a method of growing plants without using soil [2]. The system was automated using microcontrollers and sensors to keep human intervention at a minimum. An Internet of Things (IoT) network was created to improve reliability and allow remote monitoring and control if needed. The user is only required to plant a seedling and set initial parameters. Once done, the system is able to maintain the parameters and promote healthy plant growth.

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Keywords: Hydroponics; Automation; Internet of Things.

1. Introduction

The purpose of the project, Titan Smartponics, is to expand and improve the utilization of hydroponics as well as to create an environmentally independent system for indoor plant growth. In a hydroponic system, a plant is placed in a solution composed of soluble nutrients and water as opposed to soil. In most conventional hydroponic systems, parameters such as EC and pH of the water solution are set to the desired value while setting up the system [3], [4].

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There are several other parameters such as air temperature and humidity, lights, water temperature etc. which are not controlled or maintained. These parameters are important for a healthy and faster plant growth [2]. In this project, we built a system which monitors and controls all the parameters necessary for healthy indoor plant growth. In general, the process goes as follows: create a nutrient solution based on the plant being grown, apply this solution to a bed of water, place a germinated plant into the water such that the exposed roots are touching the solution. If the parameters are maintained within optimum levels, the plant should grow faster and healthier than its natural growth. Typically hydroponic systems require human interaction when it comes to the regulation of certain elements that allow the plant to grow [4]. The goal of the Titan Smartponics project is to make a system that is cost-effective and, most importantly, is completely automated and requires virtually no human interaction after placing the germinated plant into the system. The other aspect is to create a system that can be used by a typical consumer; meaning that it is relatively small and simple to use.

The Titan Smartponics project accomplishes automation by utilizing various microcontrollers, sensors, and IoT technology for remote monitoring, and control. In the most basic description of its operation, the system takes inputs from the sensors and provides a controlling action to keep different parameters in the desired range.

Automated hydroponics systems currently on the market are either very expensive or don't control all the parameters necessary for a healthy plant growth. The systems like LEAF provide the automatic control of the parameters but are priced in the high 2000's [5]. Some of the systems provided by SUPERCLOSET, are cost effective but lack the automation, monitoring and control of the environmental parameters [6]. This study provides complete automation with monitoring and control of all the parameters necessary for the growth of a plant.

2. Methodology

The system uses two Arduino boards for the analysis of the received data and control. A Raspberry Pi is used to run an open source automation software called Domoticz. Once the Raspberry Pi receives the input data, it updates the server. The system also uses a mobile app to enable monitoring and control from iOS or Android devices [7]. Because the system is relatively small (smaller than a mini refrigerator), it can fit into a small office space or a nook in the home. This accomplishes the second goal of the project. The complete automation and size are what make Titan Smartponics different from other hydroponic systems.

2.1. Hardware

In Fig. 1, the proposed system is presented. The system uses two Arduino microcontrollers acting as nodes. Nodes take the data from the sensors and send the data to a third Arduino acting as a gateway in the IoT network. NRF24L01+ radios are used for the communication between the nodes and a gateway. The gateway is connected to the Raspberry Pi running a local server which makes the data available on the web interface and mobile application. The LED's provide light to the growing plant. The lights are set to a 14 hour ON cycle to simulate daytime. A Real-Time Clock (RTC) is used to keep track of the time. The lights, along with a small exhaust fan, are controlled using a relay module. The camera mounted on the system can be accessed remotely through the Domoticz app as well as the web interface to monitor the state of the plant.

The state of the system is monitored by using various sensors. An air pump is used to infuse the water with oxygen for the plant to absorb through its roots. The system contains four sensors: an electrical conductivity probe, a pH sensor, a water temperature sensor, and an air temperature/humidity sensor, shown in Fig. 2. The electrical conductivity probe allows us to estimate an amount of salts or nutrients in the water. The pH probe must be calibrated using calibration liquids [8]. Measuring the pH allows us to properly adjust the pH of the water before putting the young plant into the system. The EC and pH probes are connected to a transmitter to convert the information received by the sensors into pH and EC values. Distilled water was used to have base pH value close to 7 and adjusted to be between 5.6 pH – 6 pH after adding nutrients. Measuring the pH of the water at consistent temperatures is vital since the pH is dependent on temperature [9]. The water was heated up to 25°C and then the pH was adjusted using acidic and basic solutions. A water heater heats up the water and automatically maintains the water at a temperature of 24°C and 25°C which is optimum for healthy root growth [2]. Carbon dioxide is supplied to the system by a carbon dioxide releasing pad.

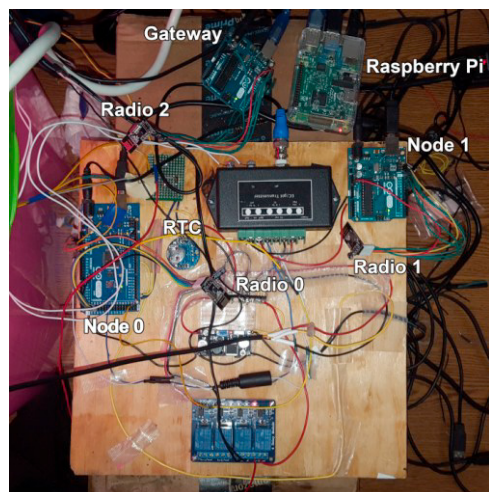


Fig. 1. Hardware components of the system.

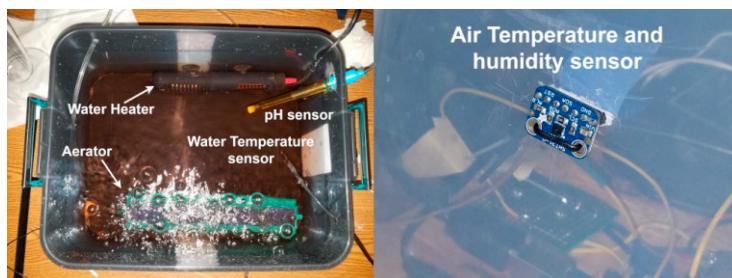


Fig. 2. Different sensors and parameter inducers.

2.2. Software

The system uses Arduinos which are programmed using the Arduino IDE. It is a modified version of the C++ programming language. This software is responsible for operating the sensors and lights. The system was configured as a sensor network in Internet of Things by using an open source API called MySensors [10], [11]. This enables the creation of nodes, gateway, and communication between them. The system uses a Raspberry Pi which is running a local server to enable remote monitoring and control of the system. A small script runs on Raspberry Pi to automatically monitor the state of the server and restarts it if necessary.

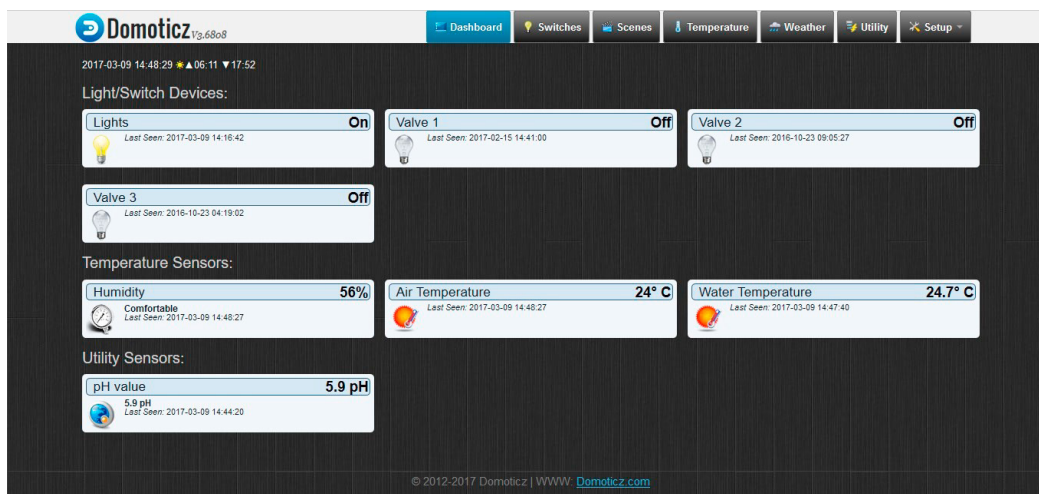


Fig. 3. Domoticz web interface.

Domoticz has a web interface that allows the user to visualize the data that is received. This interface can also take user inputs; for the Titan Smartponics system, this was used to allow the user to toggle the lights ON and OFF if they wanted to. Fig. 3 shows the web view of the interface. Each box represents either a sensor, actuator, or lights. The values presented are changed when an update in the values is reported by the system.

The main source of monitoring comes through the web interface; however, Domoticz also offers a mobile phone application that allows for more accessibility. Through the application users can monitor the same parameters as well as view the camera and maintain a control over the lights if needed. Fig. 4 shows the message sent by the system.

The system also notifies the user if values of the parameters drift out of the bounds abnormally. This can be caused by not closing the system properly, sensor failure, or a node failure. This piece of code runs on the local server which is independent of all the electronics that are responsible for the operation of the system. This means that a failure in the electronic components controlling the system will not cause these messages to be disrupted. The alert messages are achieved using a Pushbullet API and are supported by Domoticz, shown in Fig. 5. These messages can be configured to be sent to the Pushbullet application on a mobile device or a desktop machine.



Fig. 4. Abnormal parameter value message sent by the system.

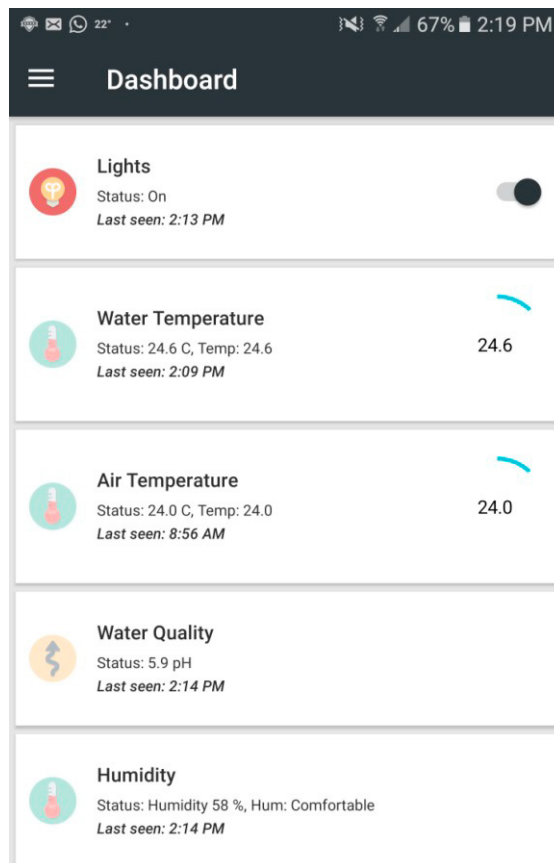


Fig. 5. Domoticz mobile application.

3. Results and analysis

Data analysis was done using the logs that were kept by the Domoitcz software. Each log is updated constantly and demonstrates the values that were reached each day. The air temperature log in Fig. 6 shows the progression of temperature from 24°C to 20°C as the day turns into night. Fig. 7 shows the amount of time the lights were ON and at what time they switched state (from ON to OFF or from OFF to ON). This is needed to make sure that the plant is getting the optimal amount of lighting. The water log keeps track of the water temperature that the plant is sitting in, shown in Fig. 8. The pH log shows the change in pH levels over time. As the plant consumes more and more nutrients from the water the pH value increases. Shown in Fig. 10. This is because of the acidic nature of the nutrients.

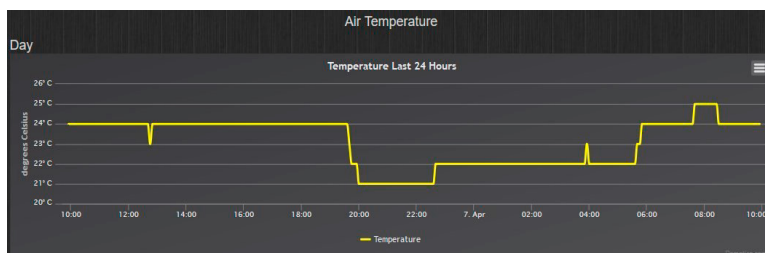


Fig. 6. Air temperature log.

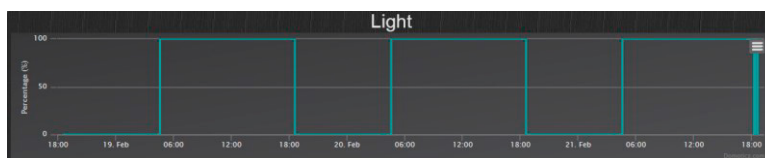


Fig. 7. Light log.

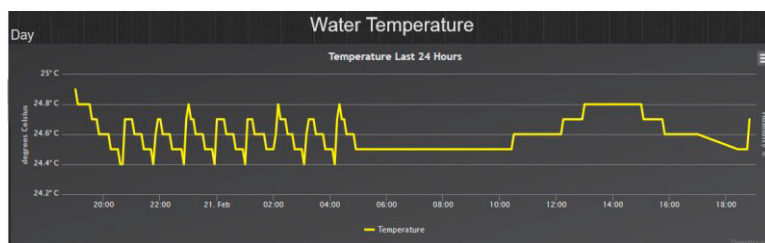


Fig. 8. Water temperature log.

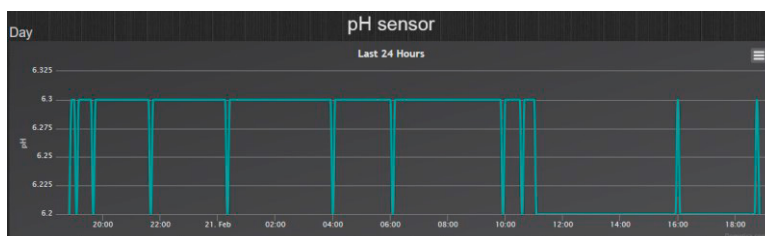


Fig. 9. pH log.

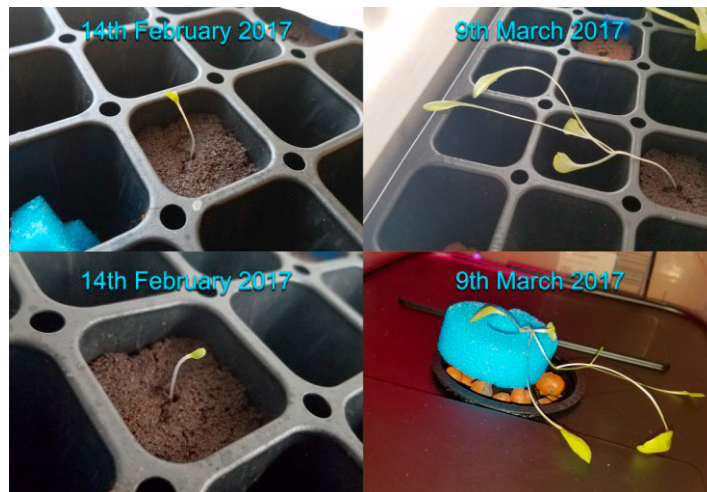


Fig. 10. Comparison of plants (top image is of outside plant; bottom image is of the plant within the system).

Each log is important in making sure that the controlling actions are keeping all parameters at optimal levels and aids in making sure that the plant flourishes. Part of the analysis for this project was through the comparison of a plant within the system and a plant outside the system. The status of both plants was monitored over the period of four weeks. Pictures were taken 3 times per week to show the difference in growth. What was concluded from this analysis was that the plant within the system grew better than the plant outside the system. This was seen through factors such as the color of the leaves, the size of the plant, and the length of the stems. Fig. 10 demonstrates the difference between the growth of the plants. The image also shows the prior mentioned factors that were considered when judging the plants' health.

4. Conclusion

The Titan Smartponics system aimed to create a fully automated hydroponic system that was low cost and fairly easy for the average user to operate. Through the usage of Arduinos, a Raspberry Pi, open source software, and a few sensors this goal was accomplished. The automated hydroponic system maintained the parameters needed for the test plant to thrive and was able to incorporate an IoT network for remote monitoring and control.

A few advantages of the Titan Smartponics system is that there is complete control over the aspects that allow a plant to grow, it can be customized to fit the need of a variety of plants, and it does not rely on the outside atmosphere or environment to succeed.

When compared to other systems, Titan Smartponics proved its importance through its complete automation aspect as well as its ability to be small enough, and affordable enough, for consumer usage.

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