Application of IoT in Deep Water Culture

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***Abstract*: In the present, World is developing to fully apply the Internet of things (IoT) into daily life because IoT is a new trend of the technology and it is very popular today. The IoT helps us link objects and mechanisms to the internet for remote control. In addition, India focuses on agriculture because India is an agricultural country and it is also the main occupation of people in the country, which makes agriculture have many formats in India, but deep water culture is an interesting new format that uses less area than others. Although deep water culture uses less space than conventional planting, it can provide many products for the farmer. In deep water culture farming, it is difficult to plant and manage if you aren't a professional farmer or don't have good knowledge about farming. For some it can be very hard to do deep water culture farming. This paper will propose an Integrated platform on deep water culture (DWC) that uses IoT devices to monitor humidity, nutrient solution temperature, air temperature, PH and Electrical Conductivity (EC). The DWC is made to support non-professional farmers, city people who have limited knowledge in farming and people who are interested in doing vertical planting in very small areas in the city such as building tops, balconies of small rooms in high-rise buildings, and in small office spaces. To make the system easy to control and easy to use, we have an android and web application to control IoT devices in the DWC and alarm users when their farm is in an abnormal situation.**

***Keywords*: Internet of Things, microcontroller Raspberry pi 3, Arduino microcontroller, Smart Farm, Automatic Planting, Web and Mobile Applications**

1. Introduction

Deep water culture is the methodology of growing plants or vegetables without soil, but using mineral nutrient solutions mixed with water and air. Since this solution will be used as a food source for the plants or vegetables, it is necessary to or manage many factors in this liquid. Some samples of variables we have to manage are the PH value or concentration and Electrical Conductivity (EC) of the nutrient solution. There will be many Devices involved and interconnected to make such a system. The main points going to be explained in the following phases of this paper.

To make such a system some main components are required and one of them would be a microcontroller, Air Compressor, Raspberry pi 3. The Arduino microcontroller was the most accessible among the developer community, and therefore was chosen for use in this project.

It will be used to control and analyze data from all interconnected devices and sensors.

The Deep water culture consists of three Phases. The first phase is about the detection sensors which include: air temperature, humidity, PH, Electrical Conductivity (EC), water temperature, ultrasonic and water flow sensors.

The second phase involves the control system which can be trained to regulate the system by monitoring the values form the sensors. The air temperature, humidity and concentration of nutrients can all be controlled so that they are in a specific range or threshold.

The last phase will look at the alarms in the application and notifications on a Smart Phone to inform the user of any changes. The user can control the devices in the DWC setup through the android application.

The Deep Water Culture (DWC) is one of the three common methods of aquaponics being utilized at present, generally developed at large-scale productions. This technology provides a detailed explanation of the main components of this method and a step by step guide to constructing a DWC.

In a deep water culture method, also known as the raft method or floating system, the nutrient-rich water is circulated through long canals at a depth, while rafts (usually polystyrene) float on top. Plants are supported within holes in the rafts by net pots. The plant roots hang down in the nutrient-rich, oxygenated water, where they absorb large amounts of oxygen and nutrients which contribute to rapid growth conditions of the plants.

The roots hang down from baskets the plants are in, and hang down directly into the nutrient solution where they are submerged. The roots remain submerged all the time 24/7. The roots don't suffocate because they get the air and oxygen they need from air bubbles rising through the nutrient solution, as well as from dissolved oxygen in the water itself.

The more air bubbles the better for water culture systems. The bubbles should be rising up through, and making direct contact with the roots as they rise to the top of the water to be most effective for the plants. There are actually two ways of providing aeration and dissolved oxygen to the nutrient solution.

2. System architecture

A literature review discusses project information in a particular subject area within a certain time period. Collecting an information from others resources such journal, articles, books summarize the needed and objective of the project.

International Journal of Research in Engineering, Science and Management
Volume-2, Issue-4, April-2019
www.ijresm.com | ISSN (Online): 2581-5792

Fig. 1. Architecture of DWC

3. SW requirements and design

Developing the software was the most time consuming part of making the controller, as this is where all the logic is. The language used is C++ and Python the Arduino IDE was used as the compiler to flash the SW on to the HW. The bulk of the SW has been built from scratch although some open source libraries have been used when interfacing with the HW.

The software not only needs to read the sensor information but also needs to be used to calibrate the pH and EC probes as well as the other sensors, to provide details of the information to the user, to function as an alert to the user if some setting e.g the pH level is too high or low and to control certain other devices, like lights and water pumps.

In order to control all the activities Integrated controller is used, In Deep water culture and we required a both hardware and software.

The controller itself works without the aid of a computer and all inputs come from an intuitive touch screen which gives warnings to the user when necessary. The SW has been designed in a way that each HW component has its own library and the UI, controller and engine have been separated out from each other. The controller is simply the loop function which is the main function of the Arduino.

The reason for this split is that in the future a different TFT screen may be used. Then only the UI section would need to be rewritten. Likewise, for the HW libraries, if in the future a different HW device is used, then only that library will need to be rewritten. If needed, just an interface wrapper would need to be constructed.

4. Controller HW requirements and design

In order for the controller to be used for growing, a study was made on how people actually use deep water culture systems and these will be the requirements both hardware and software are implemented.

In addition to this, thought has been given to the people that will actually make the deep water culture system and how the system can be made easy for them. The justification for the usage of the HW and SW is described in this paper.

The HW platform will be the Arduino Mega 2560. This will be used as it is open source and it provides enough pins to support a 3.2” TFT screen and numerous sensors. In addition, it provides access to pins which support interrupts making it ideal for this project. The available space for SW is 250KB, which is more than enough for this project. It supports EEPROM storage meaning that any user data can be permanently stored.

A. The main loop controller

The controller is the main loop of an Arduino sketch. It acts as a way to link the UI and the engine together.

B. Distribution of the SW

The SW license used for the whole project is the GNU v3 license. This was chosen as it is full Copy Right. This means that all derivative works coming from this, must themselves be open sourced and free to be modified.

C. UI usability study

The UI will be designed to make the product enjoyable to use. The graphics used will be limited however due to the restrictions of the HW. This is something that will form the basis of future work and is out of scope for this thesis. For example, making use of the SD card to load more fancy graphics.

In order to ensure that the UI would be easy to use, a UI test plan was made and people, who knew nothing of the design, were used to try it out.

5. View of DWC systems

Fig. 2. Overview, Plants are growing the Deep water Culture (DWC)

Fig. 3. Nutrition medium, the plants are growing in inorganic DWC solutions without soil

Fig. 4. Nutrition medium (lab), The view of controlled Lab for mineral nutrient solution

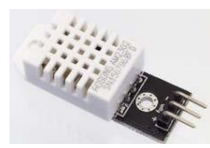
Fig. 5. Overview, Overview of DWC Environment

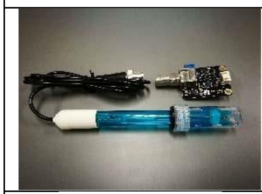
6. System overview

The Fig. 1 shows the architecture of the DWC which consists of multiple sensors, an Arduino UNO board, a Wi-Fi Shield, a Relay, an MQTT Broker, a Server, a Database and mobile user. The Arduino UNO is the main microcontroller of the system which receives data from the sensors then passes the data to other parts. The Data from sensors will be combined to one string then converted to JSON. After that, the microcontroller will send that string to the server through the MQTT Broker (A connectivity protocol for the IoT). Although the Arduino Wi-Fi board has a Wi-Fi module, it couldn't be used because the connection was too unstable and unreliable. Therefore, a dedicated Wi-Fi module had to be added, so a Wi-Fi Shield was used. The MQTT Broker is an intermediary that sends and receives data. It has 3 functions. First, the MQTT broker sends data directly to the mobile application. Second, the MQTT Broker will send information to the server. Third, it will receive commands from the mobile app. or server then send them back to the sensors. The server is used for processing and saving all values in the database.

7. Components

Table 1
Components

Device	Description
	This device is the new Arduino Uno board which comes with a Wi-Fi module. The board is based on the ATmega328P processor, and also has an integrated ESP8266 Wi-Fi Module.
	The Arduino Wi-Fi Shield allows a wireless internet connection to the Arduino module. You can connect to your wireless network by following a few instructions to start controlling your work through the internet, as always with Arduino.
	The Relay is an electrically operated switch. The 4 relays support both a Normally Open and a Normally Closed deployment, and each relay has an LED to show the status.
	A digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin.
	This sealed digital temperature probe lets you precisely measure temperatures in wet environments.
	This water flow sensor consists of a plastic valve body, a water rotor, and a hall-effect sensor. When water flows through the rotor, the rotor rolls. Its speed changes with different rates of flow. The hall-effect sensor outputs the corresponding pulse signal.
	The pump that transports water and nutrient solution from the storage buckets to the DWC gully and plants.
	A precision device that facilitates dispersion of liquid into a spray for watering the plants and reducing the temperature.

	The EC Sensor is an instrument that measures the electrical conductivity in a solution. It is commonly used in DWCs, aquaculture and freshwater systems to monitor the amount of nutrients, salts or impurities in the water.
	The PH Sensor is an instrument that measures the hydrogen-ion concentration in a solution, indicating its acidity or alkalinity of water-based solutions, expressed as PH.
	The Solenoid Valve is an electromechanically operated valve. The valve is controlled to switch on or off by an electric current through a solenoid.
	The Ultrasonic Sensor is a device that can measure the distance from an object by using sound waves. It measures distance by sending out a sound wave and listens for that sound wave to bounce back. After the sound wave bounces back, it can calculate the distance between the sensor and the object.

8. System operation

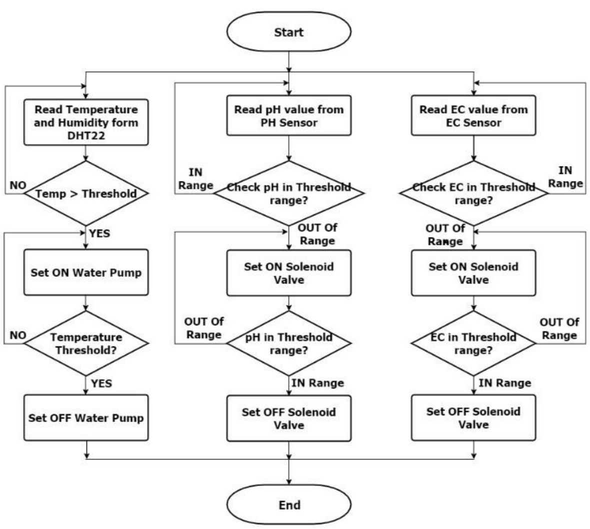


Fig. 6. The process flow of the system

The Fig. 6, shows the process of watering in this system. It starts by reading the temperature and humidity from the DHT22 (Temperature and Humidity Sensor). The temperature value has more importance over the humidity because it has a stronger effect on the plants than humidity. After that, the values will be checked that they are within the threshold. If the values aren't within the threshold, the system will turn on the water pump (by the relay) to water the setup and reduce the temperature. When the value comes into the range of the threshold, the system will turn off the water pump. The Temperature Threshold can be set to suit the season. The data or value read will be shown in the application. The unit of temperature will be in Degrees Celsius (c) and humidity will be shown in a percentage (%), and can also can be set via mobile phone.

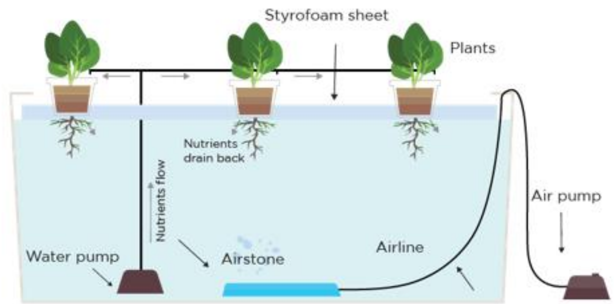


Fig. 7. The DWC system

The center flow shows the pH value management which is done by reading the PH Sensor. After receiving data from the sensors, the system will compare it to the threshold range. If the value is not in range, the solenoid valve will be turned on to release a substance, reducing the basicity/alkalinity in the nutrient solution and vice versa. The solenoid value will adjust the pH value until it reaches the set threshold.

And the rightmost flow shows the process which manages the EC value. It has a similar mechanism to the PH process, but the difference is that the value will be read from the EC Sensor and release different substances. The EC mechanism will add water when the value goes out of the threshold range and will release nutrients if the value is too low. The EC will be measured in milli seconds per centimeter (3 ms/cm).

With DWC Hydroponic system the plants roots are suspended in nutrients solution the generated air is natural air which are collected from machine tools and it directly provided to the solution, the plants are placed in the medium the roots of the plants are acquires the nutrients and unlimited supply of oxygen and they grow in the secure medium.

The deep water culture was grate for almost all plants but it especially suitable for vegetable plants.

All of data in this part will be shown on the smart phone application. In addition, the processes can also be controlled via mobile phone.

9. Experiment and results

When if we installed all the devices on the plantation, the values from the sensors installed in the plantation will be recorded and stored in database then it dynamically displays to the android application. We split the process into 3 phases and each phase has 2 parts, an automatic part and manual part which can be controlled from the mobile application.

A. *First phase*

The system's pH monitoring device was tested by manually making the solution out of range or have values out of the threshold. The automatic system adjusted the solution as promised. As for the manual pH controls through the application, the automatic system was turned off and the manual adjustment through the application is possible.

B. Second phase

Based on the survey the tests were conducted in the same way the pH monitor was tested and had positive results, functioning both automatically and manually.

C. Third phase

This tested the accuracy of the sensors. The application was tested to see if it registered the correct values from the sensors. The values sent to the application included the water flow rate, the water levels and the temperature, in which all were sent with a high accuracy.

All of the phases showed good results to make sure that the system could work correctly after the users installed all devices at their plantation. But sometimes the values shifted too much, making the variables always outside the threshold. This problem was manually solved by user adjustments at the plantation (mainly because of a bad setup) and were fixed easily, in any case this problem should rarely happen.

10. Future development possibilities

There are numerous enhancements that could be made to the HW and SW. It is possible to:

1. Add internet support and update the readings to a server.
2. Create a computer application that can be used to read the readings from the HW and display them nicely to the user.
3. Give BT support so that the controller can interact with Phones and computers.
4. Improve the UI graphics.
5. Provide multi-language support.

These are some of the things that can be developed in later versions of the SW and HW

11. Conclusion and further work

This paper which applies the Internet of Things for Deep Water culture (DWC) can help those who new farmers or people who want to have a DWC farm but do not have time to manage and plant crops. Design and implementation of automatic DWC system are presented in this paper mainly focused on measurement of conductivity of nutrient solution.

The system is useful in DWC cultivation and suitable for small space, low cost, low power and able to recycle the nutrient solution which is already used by plant. However, there is need to make this system more advanced more accurate and cost effective so that formers can use this system in large scale which is challenge that must be addressed in a future, and hence system become fully automatic by controlling the other parameter such as pH, temperature, light intensity, ambient humidity, oxygen level in water.

The designed prototype ensures of high rate of production. This system effectively makes the rural and urban household self-sustained in vegetable consumption.

Further work is applying the system in a symmetrical plantation to check the accuracy of the DWC across multiple farms in the same area; and verify that controlling via mobile application works correctly.

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