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Hydroponics System for Soilless Farming Integrated with Android Application by Internet of Things and MQTT Broker

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***Abstract*— Food, water and land, are the most essential resources to mankind, and these three resources are dependent on each other. Without proper soil or land and proper quantity of water, one cannot produce a healthy batch of crops. This is the problem of the current age due to lack of quality water and land. Climate change also affects the quantity and quality of the yield which, in coming years, may directly affect the economy of a country directly. Many countries may suffer from economical crisis due to lack of food production. A solution is needed to preserve the water resources and to maximize the profit per square feet of land which will help in production of higher quality and quantity yield, and directly or indirectly, profits the farmer or economy of the country or region. Hydroponics is such a system for farming which uses only water and nutrients for growing most terrestrial plants without the use of soil. Hydroponics can be implemented in urban location but it requires prerequisite knowledge and regular monitoring. To solve the above problem, automatizing of the entire process with sensors and micro-controller has been reported in this paper. Here an IoT based hydroponics system parameters are monitored via Android application. This will further help for improvement in system based on data generated from multiple hydroponics farms.**

Index Terms—Hydroponics, IoT, Soilless Farming, NodeMCU, Android

I. INTRODUCTION

Traditional farming can become very disadvantageous. Weeding, diseases and loss of fertile land after harvest are few drawbacks of traditional farming [1]. These disadvantages can be overcome with soilless farming method known as hydroponics uses only water and nutrients without any use of the soil. The traditional hydroponics system uses the same water in a circulatory motion with only one water tank. This type of usage of only limited amount of water helps reducing overall water usage by about 60 percent than usage of water in a traditional farming method [2]. Water soluble nutrients are used. This circulatory motion of water and nutrients form a nutrient film which is one of the most famous hydroponic setups is nutrient film technique (NFT) [3]. Traditional hydroponic system has its own limitations such as it cannot log or fetch live sensing parameters. Hydroponics is one of the best alternatives for plants on narrow land.

There have been several papers published in several journals on hydroponics systems in recent years; which suggest how hydroponic plant systems work. To supply hydroponic plant nutrients is very appropriate if done by using microprocessors for nutrient control [4]. These systems are built in many ways, supporting either vertical or horizontal farming as per the demands of the user. The setup has its own initial installation cost but; this cost can be recovered within 6 to 10 months after planting. The germination of the seed can also be done without use of soil. Hence, complete farming can be done without soil itself. Hydroponics is the best alternative way to grow plants on limited land area [5]. In recent years, there have been many research papers on hydroponics. As per research done by Kumar and Cho, the waste from hydroponics can be reused [6]. In this work monitoring several parameters is involved, which is achieved with basic sensors and one single micro-controller. Monitoring these parameters not only helps to keep a watch on the system but also data is used for further evaluation of the quality of the harvest for future scientific data analysis. Internet of Things is used to accumulate the data and store it on servers. An Android application can fetch this data, creating a more personalized setup and data. Many people are not aware of this kind of farming; Android application is a better platform to spread the knowledge than any other media. The organization of the paper is as follows. Section II contains the related work. In section III the proposed solution is reported, which includes block diagram, sensory parts, micro-controller, flowchart and circuit diagram. Section IV describes the results and discussions. Section V discusses future scope. Conclusion is given in Section VI.

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II. RELATEDWORK

Multiple communities across the globe are pursuing intelligent solutions where IoT is used to solve problems no matter the magnitude. By increase in sophisticated technology and better communication services we can easily connect to devices and share data [7]. Many new endeavors such as Big Data are using IoT as a medium to grow. Control also became more advance by the means of IoT which further advances the lifestyle of the communities.

Authors in the literature [8] presented a model for SIoT, Social IoT, which implies to use social media as a platform for exchanging data and to implement IoT for automation. The system uses micro-controllers to connect to internet and hence, creating a network of sensors which will further communicate with other micro-controller also known as node. This network is easy to establish and connect. Thus, it gives more reliable solutions.

Mr. Allen Cooper of Glasshouse Crops Research Institute (GCRI) in Littlehampton has invented the nutrient film technique (NFT) method to grow plants hydroponically in the year 1976 [9]. Authors in this literature presented a model of hydroponics greenhouse aided by IoT using a Raspberry Pi and sensors like temperature, humidity and pH. The use of cloud platform in this model helps to communicate the sensor values to a mobile application which the user can access anytime.

Authors of literature [10] have shown how different hydroponic systems are by having different temperature and nutrient content gives varied results. Those results were also compared with soil system and they have found out that hydroponics is the best system to grow plants in.

III. PROPOSED SOLUTION

A. Block Diagram

The block diagram of this work is shown in figure 1. Here, the hydroponic set up is in the field. The sensors connected to this field gathers the data from the environment and then sends that data to the micro-controller. Here, the data is analyzed for further logical tasks. This micro-controller is also connected to the internet and sends this sensor data to the MQTT cloud. The Android application in a smart phone acts as a subscriber to the MQTT cloud which enables it to get sensor data stored in the cloud.

B. Sensory Parts

The most common parameters to be sensed are temperature, pH of water, electrical conductivity of water and water tank level. The pH of the water is near neutral, 6.9 to 7, which is changed once water soluble nutrients are added. This change of the pH can be a sign of content or amount of nutrients in water. After sometime, the plants absorb the nutrient which again changes the pH of the water. So by measuring pH of the water one can determine whether it is required to put nutrients or not. Another factor in determining the nutrient amount is measuring electrical conductivity of the water. This measuring conductivity is not used in a continuous fashion but in signal at intervals of time, as ionization of water may occur. Each and every plant has its own pH and electrical conductivity values. Knowing these values is a huge advantage in making automated nutrient feeder controlled by a micro-controller. The tank level is also measured as sometime in future the plants will absorb enough water to lower the water level. Simple ultrasonic sensor, SR04, is used in this case. The temperatures sensor, DHT 11, also helps keep track of surrounding temperature which will further used for data analysis after harvest. The circuitry is very simple. NodeMCU ESP 8266 is connected with sensors also NodeMCU is coded with clouded connectivity as well.

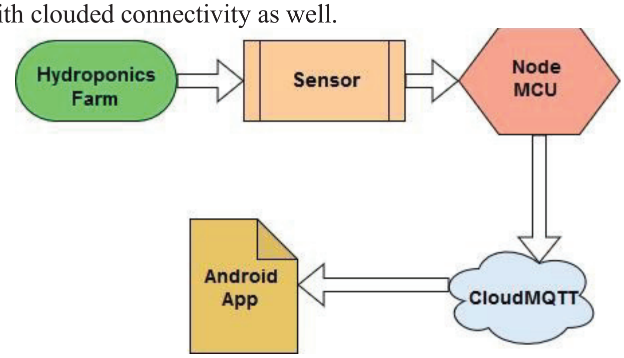

Fig. 1. Block Diagram

C. Micro-controller

The micro-controller used must have internet connectivity for IoT application. One of the famous micro-controller used in many IoT systems is NodeMCU. This micro-controller has a WiFi module which is used for connecting to internet. NodeMCU is also one of the low cost IoT micro-controller which helps in keeping the installation cost low. It runs on ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module [11]. This board can be coded by Arduino IDE which is an open source coding platform for all Arduino boards [12].

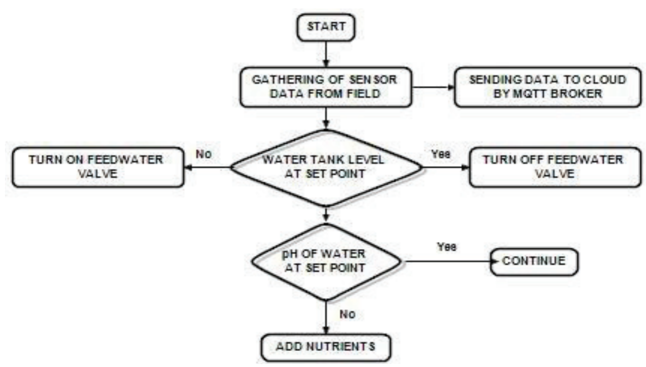

Fig. 2. Flow Chart

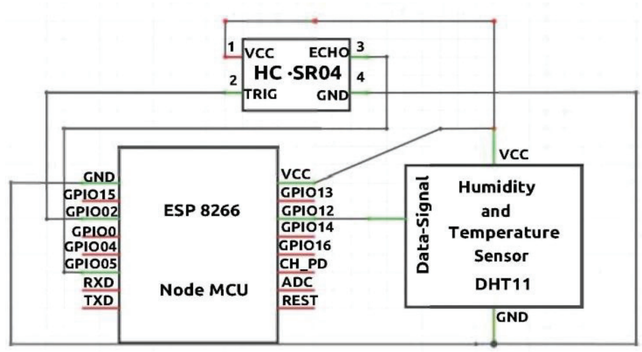

Fig. 3. Circuit Diagram

D. Flow Chart and Circuit Diagram

Figure 2 represents the overall system flowchart. At first, the system gathers parameter data from sensors into the microcontroller. The data gathered is processed for logical validity from the program written [13]. The values gathered from sensors are transmitted to the MQTT cloud server for the Android client to subscribe. Passively, if the water level of the water tank falls below a set-point, then the valve connected to the water source is actuated till the tank level reaches the set-point. Similarly, if the pH value of water is also not at set-point then the user is notified. This is an infinite loop programmed in the microcontroller. The circuit diagram is shown in figure 3.

E. Experimental Setup

The experimental setup is shown in figure 4. The hardware is consisted of a three pipe hydroponic setup in which in-total 9 plants cup holders are prepared. The setup uses a fixed water tank to form a circulatory water system. A 220V submersible pump is located inside the tank to provide water to the pipe setup. PVC pipes are used as they are cheap and easy to cut. For the germination of seeds, a large tray is used in which coco-peats are kept with seeds inside them. This setup is also modular and can be transformed to vertical hydroponic system also. Perforated plastic cups are used to contain the plant which are of exact size of the cut out made on the pipes. Around 40 percent of these cups are submerged underwater when the pipes are filled.

Fig. 4. Experimental setup

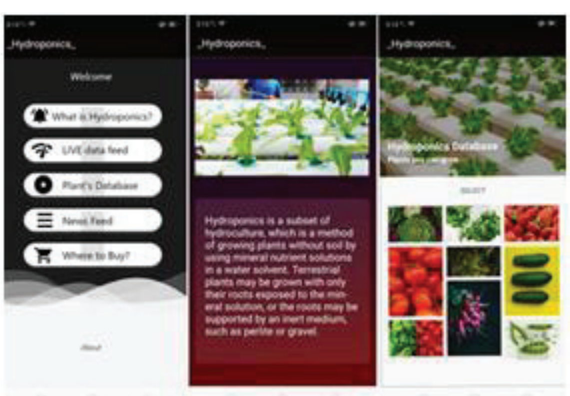

Fig. 5. Screenshots of Android Application about Hydroponics

F. Android Application and Adobe XD

The screenshots of the Android application is shown in figure 5. Android Studio is the official integrated development environment (IDE) for Google's Android operating system, designed specifically for Android development. Java and Kotlin are two programming languages used to code an Android application. The app also consists of many sections within the application like plant database, news, map showing where to buy hydroponics components and also live data feed form MQTT broker. The user experience design is done in Adobe XD [14]. It is a vector-based tool developed and published by Adobe Inc for designing and prototyping user experience for web and mobile apps. The designs developed in Adobe XD are imported in Android Studio [15].

G. MQTT Broker

MQTT stands for Message Queuing Telemetry Transport. It works on publish-subscribe-based messaging protocol, and also works on top of the TCP/IP protocol. An MQTT system consists of clients communicating with a server often called a broker [16]. An example of MQTT interpretation is shown in figure 6. A client may be either a publisher of information or a subscriber. Clients only interact with a broker, but a system may contain several broker servers that exchange data based on their current subscriber's topics. Each client can connect to the broker. In this work, CloudMQTT broker is used. Here, the Android application is one of the clients of the broker. The CloudMQTT broker website screenshot is shown in figure 7.

Fig. 6. MQTT Interpretation

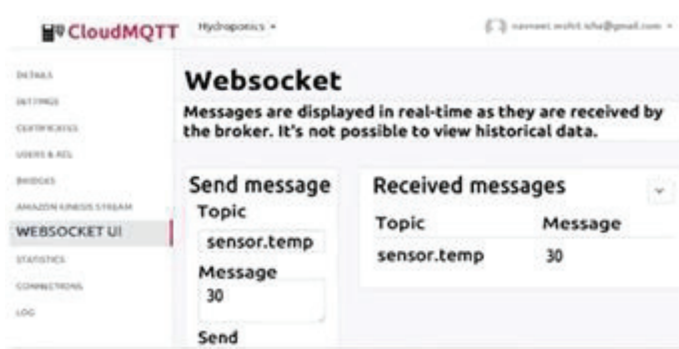

Fig. 7. Data on CloudMQTT Broker Website

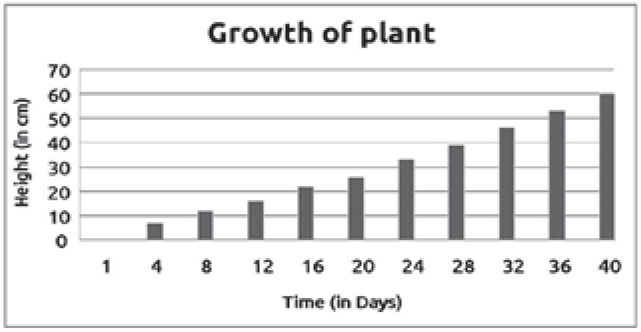

Fig. 8. The Effect of Use of Hydroponic System Compared to Soil Grown Tomato Plants on Height

TABLE I. THE HEIGHT OF TOMATO PLANT OVER 40 DAYS TIME SPAN

Time (Days)	Temperature (Celsius)	Height (CM)
1	27.3	0
4	25.9	7
8	26.18	12
12	28.52	16
16	27.45	22
20	29.1	26
24	28.93	33
28	28	39
32	27.15	46
36	27	53
40	26.12	60

IV. RESULTS AND DISCUSSIONS

The hydroponic system helps to increase in the rate of growth of plants compared with the traditional rate of growth of plants in conventional farming [10]. As per the experimental setup, as shown in figure 4, the seeds get germinated within 1 week of planting and can sustain for about 2 weeks. The rate of growth is nearly doubled in tomato plants as shown in the figure 8. The water content used is also reduced up-to 60 percent of the amount of water used in farming, as the system consists of re-circulating water from a fixed tank. The quality of the yield and the market value is also higher than soil grown plants as there is almost none weeding. The plant height is also higher than traditional soil farming. Within a noticeable time span, the plants reach a desirable height, which is indication towards a healthy plant growth as shown in table 1. This noticeable change is not observed quickly in traditional farming as compared to hydroponics system.

The pipe systems last longer if maintained and the water temperature is also at the desired level. The need of introducing water soluble nutrients has roughly a time span of around 1 week of interval. The Android application helps to monitor the parameters from anywhere in the world. There are currently no mobile applications for hydroponics available in the app store or Google play store. The offline database helps anyone anywhere to look into what kinds of plants seeds they can buy. Easy, one-tap approach to latest news and Google maps, showing hydroponics stores by using GPS, helps to be fast and accurate.

V. FUTURE SCOPE

As current technology trend in computer science is considered, some machine learning algorithms can be applicable on data gathered from all around the world by sensory parts with the help of IoT. The use of machine learning algorithm can be used to optimize the control system as to get better yield with any climatic conditions. The Android application can have several features like a community of hydroponic farmers, integrity with government and image processing using Tensorflow to make full fledged companion application to any hydroponic system.

VI. CONCLUSION

Production of terrestrial crops by the usage of hydroponic system is beneficial in proper resource management and can yield much larger amount of healthy crops than traditional farming. Integration of this type of farming with internet and Android opens up multiple opportunities to study the benefits of this system in many different regions of earth which further helps in improving the process of the system. The features of news feed or links to buy hydroponic system and its components helps to add another factor for a full, Android backed system, for the user. Community building with the help of Android application can help to spread the awareness of hydroponics and also a platform for people to get connected and to share ideas and thoughts.

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