2022 10th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO)
Amity University, Noida, India. Oct 13-14, 2022

2022 10th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO) | 978-1-6654-7433-7/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICRITO56286.2022.9964872

IoT Based Mobile Application for Monitoring of Hydroponic Vertical Farming

1st Gaganjot Kaur
Department of Electronics Engineering
Chandigarh University
Mohali, India
gaganbaidwan93@gmail.com

2nd Prashant Upadhyaya
Department of Electronics Engineering
Chandigarh University
Mohali, India
https://orcid.org/0000-0001-8266-5759

3rd Paras Chawla
Zonal Head-IT Academics
iNurture Education solution Pvt Ltd
Bangalore, India
paras.c@inurture.co.in

***Abstract*—The demand for infrastructure has tremendously increased with the population growth and it has a direct impact on the availability of agricultural land. Other factors such as climate change, declining water levels, increasing food demands, and loss of biodiversity are posing threat to agricultural production. Therefore, new agriculture techniques and practices such as vertical farming and soi-less farming have a high potential to fulfill the needs of the future world and can mitigate the requirement for arable land. This paper presents the design of an IoT-based mobile application implemented on android studio for controlling and monitoring the growth of plants using Hydroponic vertical farming. The environmental conditions and nutritional parameters, such as temperature, humidity, TDS, pH, water level, etc., recorded from the sensors are sent to the ThingSpeak cloud. The Tashi Home Pindfresh system is used for vertical farming setup and Arduino along with Raspberry Pi are used as the main controller unit.**

Keywords—Vertical farming, Mobile application, IoT, Hydroponics, Agriculture, ThingSpeak

I. INTRODUCTION

In the present scenario, the global population is a major concern as it is tremendously increasing and is expected to reach 9.7 billion by 2050 [1]. A significant proportion of this population will live in urban areas which require 70% increase in agriculture production [2]. With this rise in urban population along with climate change, arable land is becoming scarce. It is also being estimated that in the coming 50 years there will be 10% loss of cultivable land with 1% rise in the global population leading to an imbalance in the environment. So looking at these factors, efficient use of land and agricultural resources is required to meet the demand of such a growing population.

In today's scenario, new-age modern agriculture techniques such as vertical farming and soil-less farming are used to obtain high yields per unit area with minimum use of land and water [3]. These modern techniques have the potential to meet the needs of a future world with a highly increasing population and reduced arable land.

Vertical farming involves growing plants in stacked layers preferably in an indoor controlled environment but could also be done in greenhouses and rooftops [4]. It takes advantage of unused and scrap land locations under controlled environmental conditions to ensure year-long production. It gives a high yield per unit area as compared to traditional farming [5]. On the other hand, in soil-less farming techniques, plants are grown without soil using the nutrient solution, making indoor farming much easier [6]. The common soil-less techniques are hydroponics, aeroponics, and aquaponics.

Nowadays, new-age agriculture techniques involve the use of IoT platforms for controlling and monitoring plant growth and are becoming more popular in the agriculture sector [7]-[9]. An IoT-enabled aquaponics system for growing Romaine lettuce is reported in [10] for the healthy growth of plants. In this, pH, fish feeding, temperature, and light exposure are monitored and controlled via ThingSpeak IoT analytic platform. The comparative analysis of the plant growth with the traditional farming system was reported and found to be superior.

Growing vegetables using the IoT-enabled hydroponic system was reported in [11]. The proposed system has the capability of checking and refilling the nutrient solution in the system. Another, work based on an IoT-enabled hydroponic system using Ubidots IoT platform is reported in [12] for controlling and monitoring the parameters in real-time. In this system, the author uses the ESP32 module for sending the data on the Ubidots IoT platform. A solar energy-based IoT hydroponic system with reduced power consumption is reported in [13].

The fully automatic Titan Smartponics system for plant growth using hydroponic is reported in [14]. For controlling and monitoring the plant growth Domoticz open source automation software with Raspberry Pi as a control unit is used for controlling/recording the different sensor data. Domoticz which is an open free source user interface offers the integration of the cloud data over a mobile phone application which allows users to have control over their application.

In [15], the *Smart Suan Pak Nam* application i.e., a hydroponic automated system is developed using Raspberry Pi. This application also provides various functions such as to plan, manage and record the harvest data that could be used for further planning in the next grow cycle. Another approach based on fuzzy logic to control and monitor the plant growth for the hydroponic system is presented in [16]. In this multilingual mobile application is developed which helps people efficiently control and monitor plant growth in their native language.

II. OBJECTIVES

As indoor farming requires continuous monitoring, attention, and accuracy for optimum plant growth. However, it is not possible for a human being to continuously monitor the parameters required for plant growth, thus it may result in human error. Therefore, in order to reduce human intervention, IoT-based automation is an effective method for monitoring and control of plant growth by providing a user interface through mobile phones and web-based applications.

The objective of this research is to design an IoT-based automated Vertical farming system for Romaine Lettuce plant. This IoT-based system can access and control all the plant growth parameters such as temperature, humidity, pH, TDS, and water flow through mobile applications. The specific aims of the study are

- To design and develop an automated Vertical farming setup
- Enabling the technologies that can be integrated with vertical farming setup. So that the system could maintain the required growth parameters, automatically turn LED's ON/OFF, automatically balance pH and TDS and automatically maintain water level when required and
- Finally integrating the above system with the IoT platform and providing the user interface using the mobile application.

As soil-less and vertical farming are providing new innovative solutions for in-house urban farming and in the future, it may help to cater rising food demands of the urban population and water scarcity.

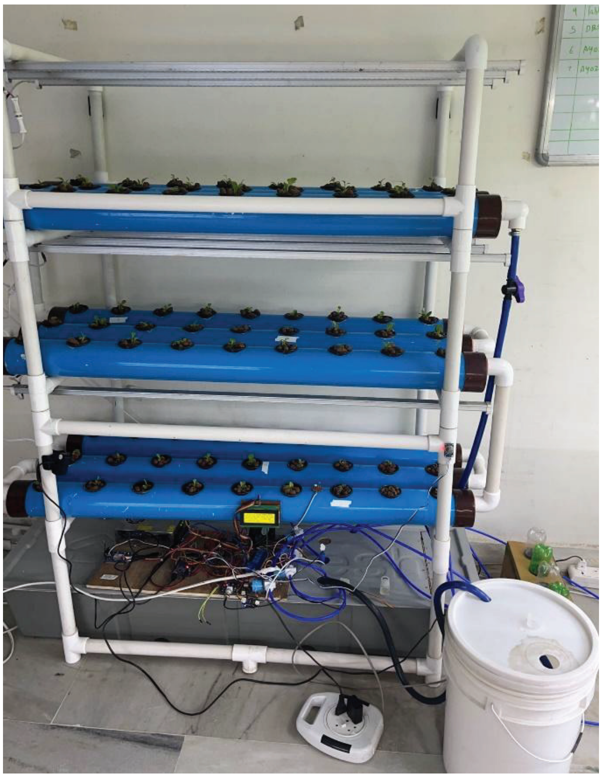


Fig. 1. Vertical Farming Hydroponic Setup

A. *Proposed Vertical Farming Setup*

In this project, the hydroponic vertical farming structure of Pindfresh Tashi Home is used. It is a 3-tier stack setup that includes three pipes on each tier. Each pipe consists of nine plantation holes and as a result, has a capacity of growing 81 plants in the 3-tier setup as shown in Fig.1. The setup also consists of the tank for a nutrient solution and pump to circulate nutrient solution to all the tiers. This setup is based on DFT (Deep Flow Technique) hydroponic techniques in which plantation is done in shallow beds and nutrient solution is constantly flowing over the roots.

B. *Controlling Environment*

To design a controlled environment various sensors are deployed in the Tashi Home setup as shown in Fig.1. Their functionality is to monitor and control various parameters, that are required to maintain healthy plant growth. These parameters include temperature, humidity, pH, TDS, water level, and light intensity [7]-[9].

The proposed Vertical farming system includes

- Arduino Mega
- DHT 11 sensor
- pH sensor
- TDS sensor
- LCD display
- Water level/ultrasonic sensor
- Water pump for nutrient circulation
- LED lights
- Flow meter
- MQ2 Gas sensor
- Webcam

All sensors are attached to the main controller unit i.e., Arduino Mega. For monitoring the environmental conditions, DHT 11 sensor is employed which is used to capture the temperature and humidity of the indoor conditions. To track the value of pH and Total Dissolved solids (TDS) present in the nutrition solution, pH and TDS sensors are connected to the controller unit. In nutrition solution, pH expresses the alkalinity of a solution on a log scale whereas TDS represents Total Dissolved solids which is a measure of micro and macro-nutrients present in the solution. The optimum values of these parameters for Romaine Lettuce is given in Table.1. Further, the Ultrasonic sensor is used to maintain the proper water level in the nutrient tank. The water pump is constantly circulating water in pipes of a vertical farming setup. Full spectrum white light LED's are used as grow lights in this setup for photosynthesis which is an alternative to natural resource i.e., sunlight. The flow meter indicates the flow status, MQ2 is for gas toxicity in terms of LPG, Methane, Propane, and CO_2. Web cam captures the images. All the recorded data is displayed to the user using 16*4 LCD display.

TABLE I. IDEAL PARAMETER CONDITIONS FOR ROMAINE LETTUCE

Parameter	Value
pH	5.5 to 6.5
TDS	560-840(in ppm)
Temperature	200C to 250C
Humidity	40-70%

C. *Application Development*

To send the data recorded from the controller unit to the IoT platform, integration of the hardware is done using ThingSpeak IoT analytic tool. It collects values from various sensors such as temperature, and humidity, and updates them on the ThingSpeak IoT platform. Further, to analyze this data recorded on the IoT service, the mobile phone application was designed for the vertical farming setup for the users using Android Studio development tools. Android Studio is the official Integrated Development Environment (IDE) for android application development. Android Studio provide some features that are used to enhance productivity while building the ***VertiFarmControl*** application. The languages such as Java, Extensible Markup Language (XML), and JavaScript Object Notation (JSON) are used. Java is a widely used language for mobile application development and is a default coding language for IDE i.e. Android studio. XML is for designing of User interface (UI). JSON is a data format for data interchange on the web.

III. VERTIFARMCONTROL APPLICATION

The user interface designed for **VertiFarmControl** application consists of Splash Screen and Login Screen. The splash screen is initially used for loading the app. It is used as an entry point of this application and has a hold-on time of five seconds which is achieved by a Handler. The handler freezes the main thread for five sec and then redirects to the login activity/screen.

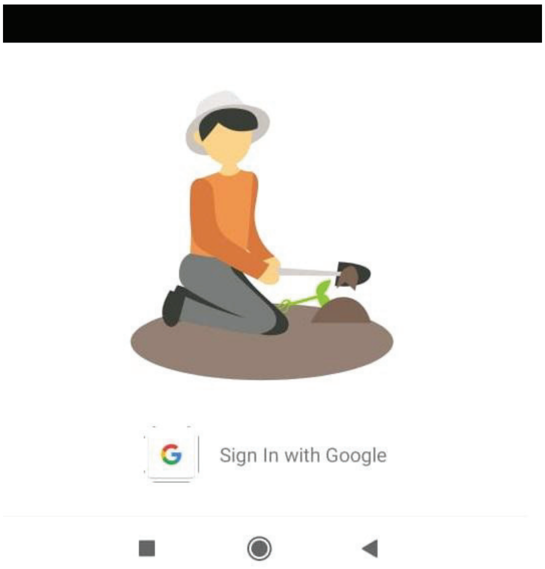
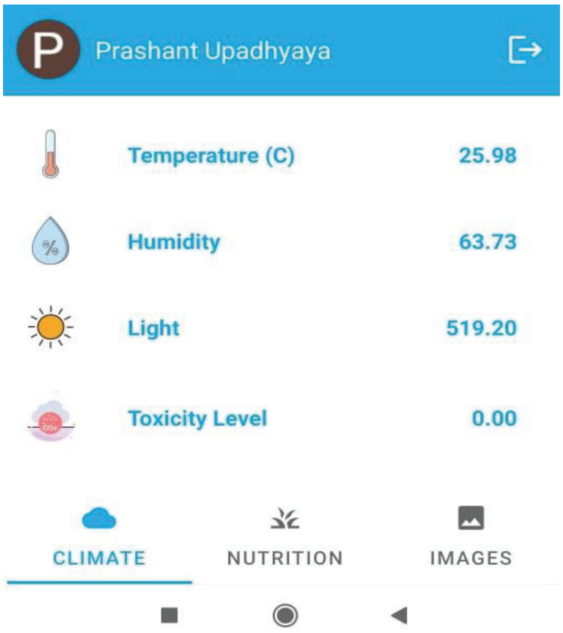


Fig. 2. Activity Screen for user account login

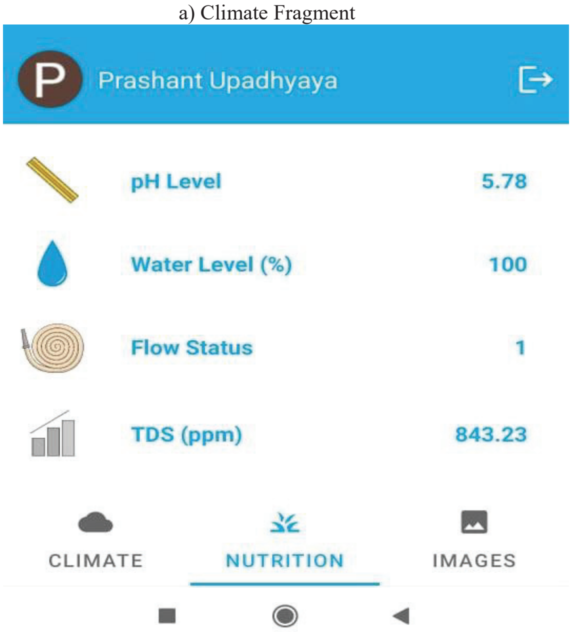
Further, *Login Screen* Fig.2 is used to authenticate the users by making them login into the application using the authentication facilitated by Firebase and Google Cloud. Each user is assigned a random and unique string as a user ID (UID). The initial details of each user such as name, email, profile picture, and UID are stored in Firebase's real-time database. The login screen determines whether the user is authenticated.

After the validation of the user account, the user is diverted to the Main Screen of the ***VertiFarmControl.*** The main screen consists of a three fragment *Climate Fragment*, *Nutrient Fragment* and *Image Fragment* as shown in Fig.3 and Fig. 4.

- ***Climate Fragment:*** This holds and displays data related to the climatic factors associated with the vertical farming which are temperature, humidity, light and toxicity level as shown in Fig.3a.



a) Climate Fragment



b) Nutrition Fragment

Fig. 3. The sample screen shot of the proposed VertiFarm Control for (a) Climate and (b) Nutrition monitoring system

- ***Nutrient Fragment***: This holds and displays data related to nutrient solution pH, TDS, its flow status and water level in nutrient tank Fig.3b.
- ***Image Fragment:*** This displays the images captured by web cam Fig. 4.

The data in fragments is fetched by an API, the response of which is in JSON format. It is then parsed using the HTTP Volley library, which is a networking library made by Google. The parsed data is then displayed on the screen with enhanced visuals to increase the user experience.The data recorded from the sensors is also available at the ThinkSpeak IoT platform as shown in Fig.5.

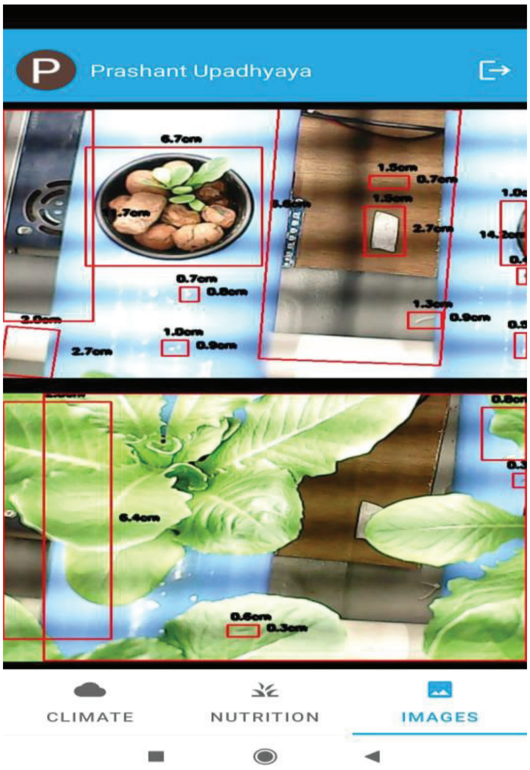


Fig. 4. Captured image of the vertical farm.

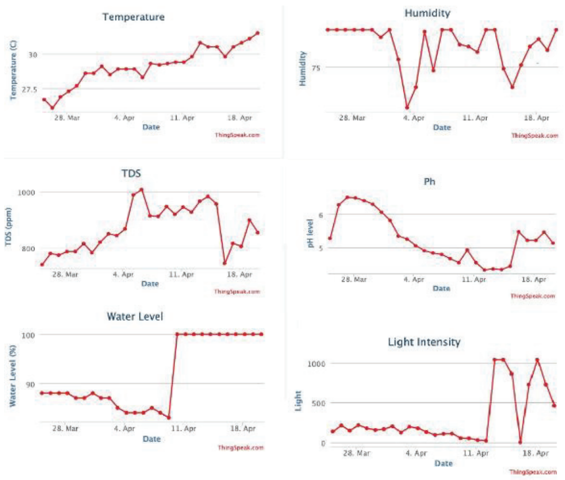


Fig. 5. Captured data using thinkspeak

IV. Conclusion and Future Scope

With increasing population, decline in arable land and climate changes, agricultural production needs to be increased. Vertical farming and soil-less farming are new age popular techniques to deal with global scarcity. Aiming at SDG goal 2 which aims to end hunger, achieve food security and improved nutrition by 2030, an IoT based automated Vertical farming system is designed which is integrated with various sensors to monitor and control various plant growth parameters. Collected data is sent to ThingSpeak IoT platform and could also be acccessed from VertiFarmControl android application. The mobile application is capable of showing live data from various sensors and alert the user when sensor value falls out of range. This automated system along with VertiFarmControl application is able to sustain healthy plant life with minimum user intervention. In future, we would also like to integrate the farming assistance in the developed application which can guide the farmer about the best technique used for the latest agriculture plant growth.

References

[1] United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022: Highlights. UN DESA/POP/2022/NO.3.

[2] United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization Prospects 2018: Highlights. ST/ESA/SER.A/421..

[3] G. L. Barbosa, F. Daiane, A. Gadelha, and N. Kublik,`` Comparison of Land , Water , and Energy Requirements of Lettuce Grown Using Hydroponic vs . Conventional Agricultural Methods," International Journal of Environmental Research and Public Health ,vol.12,pp. 6879–6891,2015.

[4] D. Despommier, ``The vertical farm: controlled environment agriculture carried out in tall buildings would create greater food safety and security for large urban populations". J. Verbr. Lebensm. vol. 6, pp. 233–236, 2011. https://doi.org/10.1007/s00003-010-0654-3

[5] D. Touliatos, I. C. Dodd, and M. Mcainsh, ``Vertical farming increases lettuce yield per unit area compared to conventional horizontal hydroponics," Food and Energy Security, vol. 5, pp. 184–191, 2016.

[6] S. Millam and S. K. Sharma Chapter 32- Soil-Free Techniques. Potato Biology and Biotechnology. Elsevier B.V., pp. 705-716, 2007. ISBN 9780444510181

[7] M. I. H. bin Ismail and N. M. Thamrin,``IoT implementation for indoor vertical farming watering system," 2017 International Conference on Electrical, Electronics and System Engineering (ICEESE), 2017, pp. 89-94, doi: 10.1109/ICEESE.2017.8298388..

[8] J. G. Chand, K. Susmitha, A. Gowthami, K. M. Chowdary and S. K. Ahmed, "IOT-Enabled Vertical Farming Monitoring System Using Big Data Analytics," 2022 Second International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT), 2022, pp. 1-6, doi:10.1109/ICAECT54875.2022.9807888

[9] M. Mehra, S. Saxena, S. Sankaranarayanan, R. J. Tom, and M. Veeramanikandan,``IoT based hydroponics system using Deep Neural Networks," Computers and Electronics in Agriculture, vol. 155, pp. 473–486, August,2018, doi: 10.1016/j.compag.2018.10.015.

[10] F. L. Valiente et al.,``Internet of Things (IOT)-Based Mobile Application for Monitoring of Automated Aquaponics System," 2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology,Communication and Control, Environment and Management (HNICEM), 2018, pp. 1-6, doi: 10.1109/HNICEM.2018.8666439

[11] K. Kularbphettong et al.,`` An Automated Hydroponics System Based on Mobile Application," International Journal of Information and Education Technology, 2019, pp. 548-552, doi: 10.18178/ijiet.2019.9.8.1264

[12] R. B. Harikrishna, R. Suraj, P.N.Paramasiva, A. Anand Kumar A and S. Pandiaraj,"Greenhouse Automation Using Internet of Things in Hydroponics," 2021 3rd International Conference on Signal Processing and Communication (ICPSC), 2021, pp. 397-401, doi: 10.1109/ICSPC51351.2021.9451668

[13] C. Joshitha, P. Kanakaraja, K. S. Kumar, P. Akanksha and G. Satish,``An eye on hydroponics: The IoT initiative," 2021 7th International Conference on Electrical Energy Systems (ICEES), 2021, pp. 553-557, doi: 10.1109/ICEES51510.2021.9383694.

[14] A. Zaheer, K. George and V. Palande, "ScienceDirect ScienceDirect Fully Automated Hydroponic System for Indoor Plant," Procedia Computer Science, vol. 129, pp. 482–488, 2018, doi: 10.1016/j.procs.2018.03.028.

[15] C. Peuchpanngarm, P. Srinitiworawong, W. Samerjai and T. Sunetnanta, "DIY sensor-based automatic control mobile application for hydroponics," 2016 Fifth ICT International Student Project Conference (ICT-ISPC), 2016, pp. 57-60, doi: 10.1109/ICT-ISPC.2016.7519235

[16] S. Biswas, B. Deka, S. Dash and K. Rout,``IoT-based fuzzy logic -controlled novel and multilingual mobile application for hydroponic farming", In Intelligent Data-Centric Systems, AI, Edge and IoT-based Smart Agriculture,Academic Press, 2022,Pages 31-42, ISBN 9780128236949, https://doi.org/10.1016/B978-0-12-823694-9.00027-X.