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IoT-based Mobile Application for Monitoring of Hydroponic Vertical Farming

AVD. Suresh Kumar, M. Tech, M. Gayathri, D.V.M. Durgesh Kumar, K. Vishnu Vardhan,
N. Sanjay Varma

HOD & Associate Professor, Dept. of EEE, PSCMR College of Engineering and Technology, Krishna, A. P, India

Dept. of EEE, PSCMR College of Engineering and Technology, Krishna, Andhra Pradesh, India

ABSTRACT: Hydroponic vertical farming is widely seen as a very productive form of farming, at least to some extent. It is a technique of growing plants without soil, which also contributes to the change in how we use space and our resources more efficiently. However, these types of farm setups need a certain environment for the plants to grow and complete their production cycle. One way to achieve this is by continuously monitoring different environmental and nutrient parameters, which is very difficult to do manually. To address this issue, here is a project for an IoT-based mobile app system that monitors and controls hydroponic vertical farming through automation. The brain of the system is an Arduino Mega 2560 which is the primary controller. It collects live data from a range of sensors including a pH sensor for checking the nutrient solution, a DHT11 sensor for recording temperature and humidity, and a soil moisture sensor for determining moisture levels. Besides these, a color sensor and an IR sensor are used to analyze the health and behavior of the plants. The collected data can be displayed locally on an LCD and it is also transmitted remotely via a NodeMCU module.

KEYWORDS: Hydroponic vertical farming, Internet of Things (IoT), smart agriculture, Arduino Mega 2560, real-time monitoring, mobile application, automation, pH sensor, environmental sensing, nutrient management.

I. INTRODUCTION

Agriculture is partly shifting to adapt the increasing population, limited land availability, and the necessity of resource sustainability. Methods such as traditional farming, which use the soil and depend on large land areas, usually face problems with the unpredictable nature of the climate, water shortage, and the inefficient use of resources. In this situation, hydroponic vertical farming is being recognized as a potential substitution because it enables the growth of plants without soil by the use of nutrient-filled water solutions and in the arrangements of vertically stacked plants. This method is the one to drastically lower the quantity of water needed, make the best use of space, and even allow growing in cities. Conditions, factors that influence plant growth and yield, include pH level temperature humidity, and nutrient concentration. Slight changes away from the most suitable conditions can cause a disturbance in the plant's nutrient supply, a decrease in the rate of growth, or even stress. While in conventional agriculture, the soil can be considered as a buffer of sorts, hydroponic systems need to be checked and managed very regularly because of their high sensitivity. Manual monitoring is still predominant in many small rural home setups. Users (for example, farmers) periodically check readings on the sensors, or visually inspect the condition of plants. But there are many drawbacks to this method. First of all, it is very time consuming, and since people are involved, it is also quite error-prone. At the same time, this way of monitoring is totally incapable of giving the information in real-time. The changes that happen in nature suddenly may be missed, and then the corrective measures are taken late, and there may be losses in the crops. Pumping and irrigation systems that are operated manually not only lead to lower efficiency but also require more human input. Embedded systems combined with the Internet of Things (IoT) technology provide a smarter and more reliable way of dealing with these problems. IoT allows for data gathering as it happens, it enables the monitoring from a distance and also the intelligent management of agricultural systems. By linking together the sensors, the controllers, and the communication modules, it is even feasible to have a continuous observation of the environmental conditions, and at the same time, based on certain levels that have been set, the responses could be automatically sent out. This way accuracy is significantly improved, and at the same time, the human in the loop for these operations is greatly reduced finally this also contributes to the overall work-efficiency of the system. This project's proposal details an IoT-based mobile application for monitoring and controlling hydroponic vertical farming. Arduino Mega 2560 is a drastic change in system as the main controller with other interfaces of different sensors from which environmental and plant-related data are taken. A pH sensor is used for monitoring the nutrient solution quality, DHT11 sensor senses the temperature and humidity; soil moisture sensor is there for checking moisture level in the growth medium. user-friendly, which



means it can very well adapt to the current agricultural methods while at the same time effectively addressing the problems related to efficiency, accuracy, and resource optimization.

Key characteristics of the existing system include:

- Basic Microcontroller Usage – Limited processing speed and control accuracy.
- Low-Resolution PWM Generation – Inefficient speed modulation with less precision.
- No Real-Time Feedback – Absence of dynamic control or response to varying load conditions.
- Limited Scalability – Not suitable for complex or high-performance EV applications.
- No Support for Advanced Features – Harder to implement advanced automation or wireless control.
- Less Integration with IDEs – Limited software support, leading to complex development cycles

Proposed System

The system has been developed to track, manage, and automate hydroponic vertical farming through the interaction of embedded systems, sensors, and Internet of Things (IoT) technologies. Methodology is a sequential plan according to which several hardware components and software components are combined to create the right environment for the plants to grow. The proposed system will keep track of the farming environment continuously, make the best use of resources, and require very little human intervention while at the same time providing high accuracy and reliability.

Key features of the proposed system include:

- Microcontroller – Arduino mega 2560 – Offers high-speed, real-time processing and precision control.
- Mobile application interface – Enables users a continuous remote control for monitoring vertical farming
- Arduino IDE Integration – Simplifies development and leverages open-source libraries.
- Robotic Platform Implementation – Enables mobile testing.
- Scalability and Modularity – Supports integration of sensors, wireless modules, and automation features.
- Low-Cost & Efficient – Ideal for research, academic projects, and early-stage EV prototyping.

II. SYSTEM MODEL AND ASSUMPTIONS

In designing an 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 application. 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.

III. EFFICIENT COMMUNICATION

In an IoT-Based Mobile Application for Monitoring of Hydroponic Vertical Farming, efficient communication is essential to ensure accurate control, real-time monitoring, and safe operation. The Microcontroller – Arduino mega 2560 plays a central role not only in executing the control algorithms but also in managing communication between different hardware and software components within the system. It interfaces with speed sensors, motor driver circuits, power management systems, and external control modules as the brain of the system where the raw data collected by all sensors are analyzed and processed. For this project, an Arduino Mega 2560 was selected as the primary controller because of its capable nature of handling multiple sensor and output control tasks simultaneously with ease. It keeps on receiving live running data from sensors like pH sensor DHT11 soil moisture sensor, color sensor, and IR sensor. If any sensor helper value is out of their proper range, then the system marks that as an unhealthy working mode and gets ready for fixation. The brain status updates in this level are done by the programmed rules and if-else conditions. Take a



case of that the soil moisture remains at a low level, or some circulation is needed for the nutrient solution. Here, the controller dispatches instructions to energize the relay modules. In the same way, change in temperature or pH may call for the system to do one or more of the suitable responses. This way the system is capable of acting fast and keeping the environment stable even without human intervention all the time. Communication between various system components like sending the processed data to LCD for local display as well as interacting with NodeMCU and Bluetooth module for monitoring purposes both remote and local to be connected to the internet and allow sharing of real time data to the users while at the same time the users are able to control the system remotely.

Overall, the Microcontroller – Arduino mega 2560 provides a highly integrated and flexible communication platform for Vertical Farming. By combining multiple high-speed interfaces and robust protocol support, it ensures seamless data exchange between all critical components. This reliable communication infrastructure supports precise speed regulation, effective coordination between subsystems, and adaptability to real-time driving conditions.

IV. MICROCONTROLLER – ARDUINO MEGA 2560

The Arduino Mega 2560 has a central role in the entire setup as the master "brain". It manages the collection of sensor data, the data processing and issuing of control commands if certain preset conditions are met. Also, it is equipped with a very large number of input/output pins which allows it to work with many sensors and modules simultaneously. The pH temperature humidity soil color and IR sensors continuously sending their information to Arduino. On processing the information, Arduino measures the values with the normal ones to make sure the plant's environment is the most suitable one.

Once Arduino understands the data thoroughly, it will communicate the rest of the system by only turning on/off the water pumps through relays. Besides, it is connected with NodeMCU and Bluetooth module to share data and offer the user a more interactive experience.

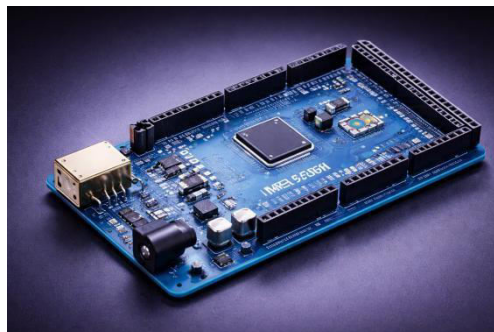


Fig. 1 MICROCONTROLLER – ARDUINO MEGA 2560



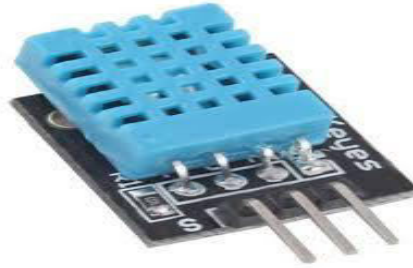
Fig. 2 pH Sensor for Nutrient Monitoring

One of the most significant components of a hydroponic system is the pH sensor as a pH sensor measures the acidity/alkalinity of the nutrient solution. The pH level must be maintained at the proper level for plants to absorb nutrients efficiently. The sensor monitors the pH level continuously and communicates with the Arduino device for data transfer. When the level rises or drops beyond the set limits, the system can make a correction through the automation layer. Hence, the nutrient environment that supports healthy plant growth is maintained.



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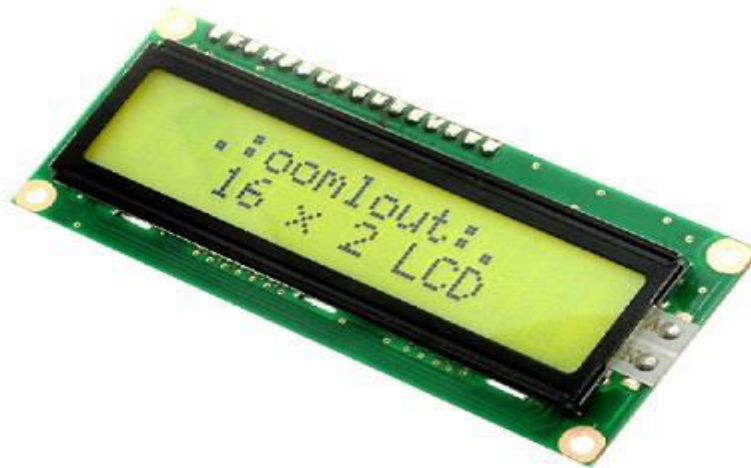
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**Fig. 3 DHT11 Sensor**

The DHT11 sensor is used to measure ambient temperature and humidity, which are essential environmental parameters for plant growth in a hydroponic system. Proper temperature and humidity levels help in maintaining a stable growing environment, ensuring that plants can absorb nutrients efficiently and grow at an optimal rate. The sensor continuously monitors these conditions and provides real-time data to the controller for analysis. The data collected by the DHT11 sensor is used by the system to detect any variations from the desired environmental range. If abnormal conditions such as high temperature or low humidity are observed, the system can take necessary actions to restore balance. This early detection helps prevent plant stress, improves overall plant health, and ensures consistent growth. By maintaining stable environmental conditions, the sensor contributes significantly to the efficiency and reliability of the hydroponic farming system.

V. USER INTERFACE

The term LCD stands for liquid crystal display. The LCD module displays sensor readings and system status in real-time. It shows users at a glance some of the major parameters such as pH level temperature humidity, and parts of the system that are running. By enabling direct system monitoring without the need for other devices, this element raises the convenience level of the system significantly. Setting up and inspecting the system become easy since the display helps in understanding the system's working and locating errors swiftly.

**Fig. 4 LCD 16×2 Pin Diagram**

The 16×2 LCD pinout is shown below.

- Pin1 (Ground/Source Pin): This is a GND pin of display, used to connect the GND terminal of the microcontroller unit or power source.
- Pin2 (VCC/Source Pin): This is the voltage supply pin of the display, used to connect the supply pin of the power source.
- Pin3 (V0/VEE/Control Pin): This pin regulates the difference of the display, used to connect a changeable POT that can supply 0 to 5V.



- Pin4 (Register Select/Control Pin): This pin toggles among command or data register, used to connect a microcontroller unit pin and obtains either 0 or 1(0 = data mode, and 1 = command mode).
- Pin5 (Read/Write/Control Pin): This pin toggles the display among the read or writes operation, and it is connected to a microcontroller unit pin to get either 0 or 1 (0 = Write Operation, and 1 = Read Operation).
- Pin 6 (Enable/Control Pin): This pin should be held high to execute Read/Write process, and it is connected to the microcontroller unit & constantly held high.
- Pins 7-14 (Data Pins): These pins are used to send data to the display. These pins are connected in two-wire modes like 4-wire mode and 8-wire mode. In 4-wire mode, only four pins are connected to the microcontroller unit like 0 to 3, whereas in 8-wire mode, 8-pins are connected to microcontroller unit like 0 to 7.
- Pin15 (+ve pin of the LED): This pin is connected to +5V
- Pin 16 (-ve pin of the LED): This pin is connected to GND.

The features of this LCD mainly include the following.

- The operating voltage of this LCD is 4.7V-5.3V
- It includes two rows where each row can produce 16-characters.
- The utilization of current is 1mA with no backlight
- Every character can be built with a 5×8 pixel box
- The alphanumeric LCDs alphabets & numbers
- Is display can work on two modes like 4-bit & 8-bit
- These are obtainable in Blue & Green Backlight
- It displays a few custom generated characters

VI. PROTOTYPE OF PROPOSED SYSTEM

(i) Components Used:

- ESP8266 / ESP32 / Arduino
- DHT11 / DHT22 Sensor
- pH Sensor
- Water Level Sensor
- Color Sensor
- Hydroponic vertical setup
- Power supply unit
- IP web camera
- Display
- Relay
- IP web camera
- Nodemcu
- 12v Adapater

Working Principle:

1. Environmental sensors: (pH, Color, Soil Moisture, DHT11) continuously monitor the physical conditions of the plant.
2. Microcontroller: (central block) processes these incoming analog and digital signals against pre-defined software thresholds. If conditions like low soil moisture are met, the controller triggers the Relay to switch on the AC Water Pump.
3. ESP32 Cam: captures visual data, while the NodeMCU uploads all system telemetry to the cloud via WiFi.
4. Display Unit: A LCD provides a real-time local visual interface, displaying current sensor data and system status for the user.
5. Bluetooth Module: enables short-range wireless control, allowing a user to manually override the pump or view data on a phone.



Fig. 5 Vertical Farming Hydroponic Setup

This fig 5 shows , 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.5. 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.

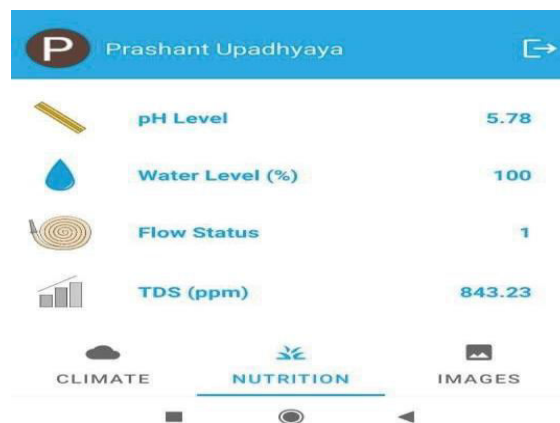


Fig. 6 The sample screen shot of the proposed VertiFarm Control for (a) Climate and (b) Nutrition monitoring system

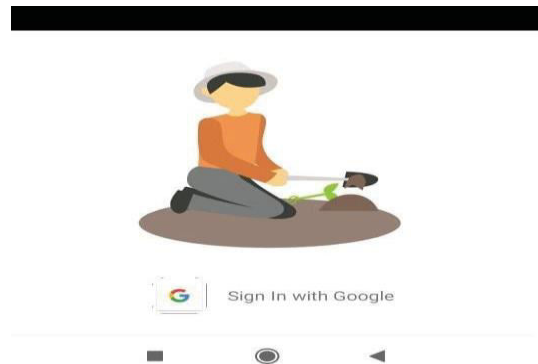


Fig.7 Login Screen

Further, *Login Screen* Fig.7 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.

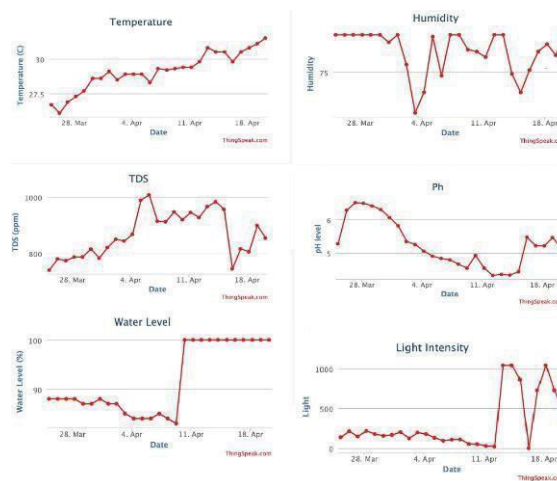


Fig.8 Captured data using thinkspeak

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.

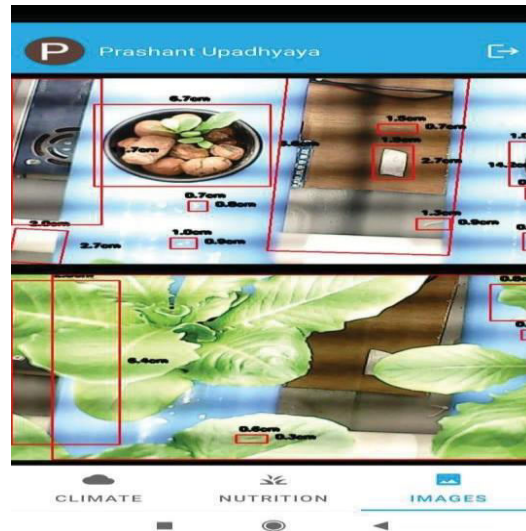


Fig. 9 Captured image of the vertical farm.

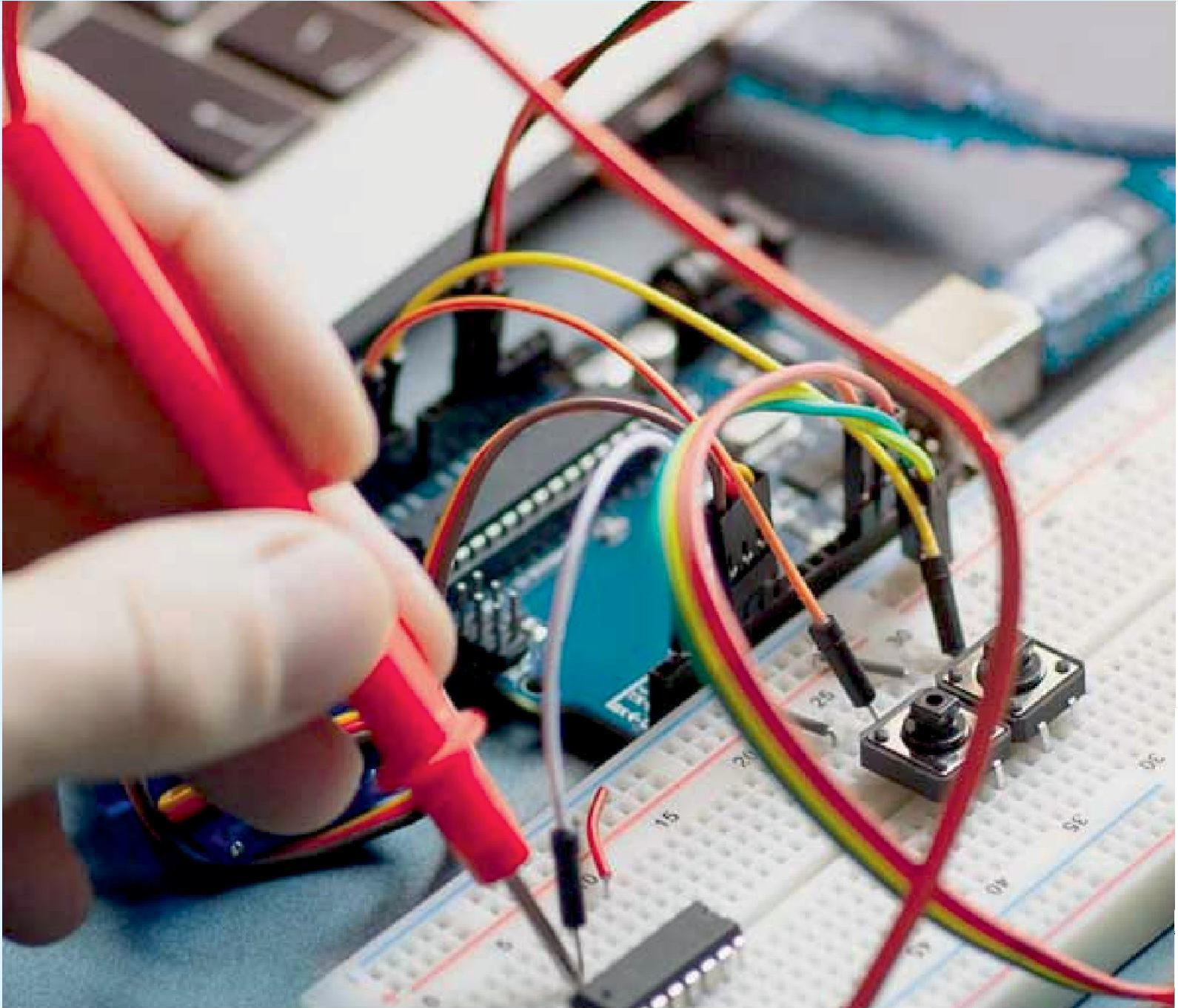
The fig 8 & 9 shows After the validation of the user account, the user is diverted to the Main Screen of the Verti Farm Control. The main screen consists of a three fragment Climate Fragment, Nutrient Fragment and Image Fragment as shown in Fig.6 Climate Fragment: This holds and displays data related to the climatic factors associated with the vertical farming which are temperature, humidity, light and toxicity level

VII. CONCLUSION

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 accessed 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.

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