

DIGITAL FARMING USING AEROPONICS

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Abstract - The digital farming using Aeroponics for smart cities is an automated system in farming without using soil. This system is designed to revolutionize the farming sector in the present era of automation. The outcome of the project is a simple system capable of cultivating plants indoors without using soil, irrespective of external climate conditions. This system employs a root chamber, shoot chamber and control section. The hardware is designed to be simple and scalable. The sensors in the root and shoot chamber are controlled by Atmega328 (Arduino mini pro) which is connected to a system on chip Raspberry Pi3B+ in the control section. The prototype model is designed and the practical implementation may have some changes. In large scale, this system is very well capable of helping farmers to reduce their field work and in small scale, it can help normal people who wish to do farming at their home itself.

Index Terms— Aeroponics, chip Raspberry Pi 3B+, arduino, sensors, plant

INTRODUCTION

By the year 2050, the population of earth is expected to rise by 3 billion people. It was found that approximately 109 hectares of additional traditional farm land will be needed to feed them. Only 80% of the Earth's arable land suitable for farming now. Roughly 15% of this land has been rendered unusable for farming due to poor management and climate change has claimed even more. Another issue is that crop yields are highly dependent on weather. Climatic change has generated shifting weather patterns and extreme weather events that make it more difficult for farmers to cultivate. Implementing Modern farming methods impacts soil by the use of nitrogen fertilizers. This erodes the soil ability to hold the nutrients. Thus the agricultural land becomes unproductive [1]. Today's agricultural practices majority rely on irrigation rather than rainfall, which in turn depletes groundwater reserves and these have huge impact on the soil. Rapid urbanization and industrialization leads to loss of agricultural land, population growth and these trends will cause massive food shortage in the future. So these problems can be overcome by adopting soilless indoor farming of which aeroponics is one of the technique [2][3]. Aeroponics is a process of growing plants in an air or mist environment without the use of soil. NASA's research on aeroponics have proven that this technique can reduce water usage by 98%, the usage of fertilizer by 60% and pesticide usage by 100% while increasing crop yields. The main focus of this project is on constructing an automated system that regulates and monitors the aeroponics system. This will be accomplished by the use of mist makers, pH sensor, temperature, humidity, intensity regulator and a single board computer. While a mobile app will be employed to allow the user to monitor and interact with the system in

ease. The user will also be warned in case of any malfunction so that necessary action could be taken.

I. PROPOSED SYSTEM

Aeroponics system is a scheme for growing plants without soil by employing necessary nutrients with new method of arrangements. An automated technology needs for cultivation and for productivity is sophisticated computer equipment for decision making, mobile to monitor, sensors. The exclusive reason to reduce human efforts and help in cultivating more with different weather condition with high technology in assistance of sensor systems, PC's, Raspberry Pi3B+. The figure1 below block diagram explains the process of aeroponics technology. The system consists of two different chambers, one for the shoot system and the other for the root system. This is done to ensure that the climatic conditions of the root system and shoot system are completely independent of each other farming.

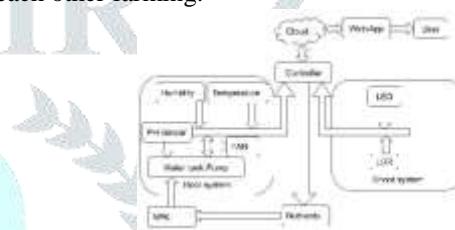


Figure 1: Block Diagram of aeroponics system

Proposed design: The aeroponics culture technique is an optional device of soilless culture in growth controlled environments such as greenhouses or grows chambers. This method consists of enclosing the root system in a dark chamber and supplying a nutrient solution. The system comprises of Raspberry pi3B+, Temperature and Humidity sensor, Light sensor, Water level sensor, pH sensor, Grow led panel, Water submersible pumps, Nutrient solution.

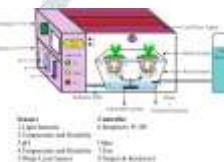


Figure 2: Proposed design of aeroponics system

Shoot chamber: From the figure 2 shows the shoot chamber will host a light sensor, temperature sensor, exhaust fan to regulate the air pressure and temperature in the chamber. An array of LED lights will be fixed to the zenith of the chamber and the brightness of these lights will be controlled according to the optimum light intensity required by different plants for photosynthesis. Temperature and humidity regulation is done using exhaust fans and sensors. The exhaust fan will reduce the temperature and humidity of the chamber if it increases above the optimum value.

Root chamber: From the figure 2 shows the root chamber will have its own sensors to regulate the temperature and humidity of the chamber. The nutrient reservoir will be constructed which comprises nutrient solutions. These solutions will be supplied through solenoid valves. A couple of mixers in the reservoir will ensure that the composition of the nutrient solution within the reservoir stays consistent. A pH sensor will monitor the pH solution according to the needs of the plant. Water level sensor monitors the water level of the reservoir and it will replenish the reservoir if the solution drops below the given level.

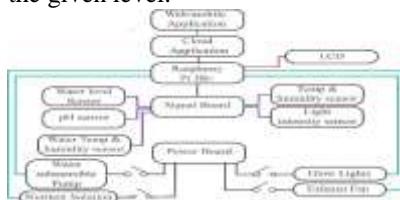


Figure 3: Diagram of Aeroponics system

The hardware: This utilization of aeroponics system is basically consists of different components like Raspberry pi, pH sensor, DHT22, etc. The aeroponics chamber is made up of a number of important components namely ATmega328 microcontroller, raspberry pi, temperature and humidity sensor etc.

ATmega328 MICROCONTROLLER: An ATmega328 microcontroller is popular as Arduino mini-pro microcontroller, pictured in Figure 4 will be used to control the actuators, sensors and future electronics. This platform was chosen for its low cost, general availability, hack ability, expandability through shields, the expansive learning resources available, the strong DIY community already using the platform, and the fact that it is open source. In addition, arduino programs are written in the C language and therefore very familiar to many. The Arduino Pro Mini is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, an on-board resonator, a reset button, and holes for mounting pin headers. A six pin header can be connected to an FTDI cable or Sparkfun breakout board to provide USB power and communication to the board. There are two version of the Pro Mini.



Figure 4: Atmega328 Microcontroller

RASPBERRY PI3B+: Raspberry Pi is a series of small single-board computer with a 1.2 GHz 64-bit core processor as shown figure 5 on-board WiFi, bluetooth and USB boot capabilities. Raspberry pi will be used for web application and automation.



Figure 5: Raspberry Pi3B+

Humidity and temperature sensor: The DHT22 is a basic, ultra low-cost digital temperature and humidity sensor which

as shown in figure 6. It uses a capacitive humidity sensor and a thermostat to measure the surrounding temperature and humidity in air, and outputs a digital signal on the data pin. It has excellent quality, fast response, anti-interference ability and high performance.



Figure 6: The humidity and temperature sensor

The specifications of the temperature and humidity sensor are low cost, 3.5 to 5.5V power and I/O, good for humidity range: 0% to 100% readings with ± 1 , good for -40°C to 80°C temperature readings ± 0.5 , °C accuracy.

Light intensity sensor: The figure 7 shows as LDR is a special type of resistor that allows higher voltages to pass through low resistance whenever there is a high intensity of light, and passes a low voltage (high resistance) whenever it is dark. The LDR gives out an analog voltage when connected to VCC of 5V, which varies in magnitude in direct proportion to the input light intensity on it. That is the greater the intensity of light, the greater the corresponding voltage from the LDR will be. Since the LDR gives out an analog voltage, it is connected to the analog input pin on the arduino.



Figure 7: The light intensity sensor

The specifications of the LDR are maximum power dissipation 200mw, maximum voltage at 0 lux: 200v, Peak wavelength of 600nm, minimum resistance at 10lux. 8k ohm, maximum resistance at 10lux, 4.5k ohm, type of resistance at 100lux 0.7k ohm.

pH sensor: To measure pH probe along with the resistors are used. Two electrodes generate a voltage directly proportional to the pH of the solution. At a pH of neutral, the electrodes will produce zero volts between them. At a low pH a voltage will be developed of one polarity, and at a high pH (caustic) a voltage will be developed of the opposite polarity. The pH sensor probe is as shown in figure 8



Figure 8: The pH sensor probe

The equivalent circuit diagram of a typical pH probe circuit is as shown in figure 9

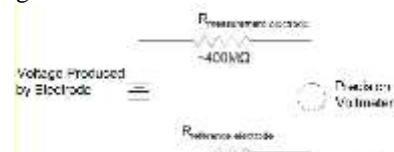


Figure 9: The circuit diagram of a typical pH probe circuit

Grow led panel: A grow light or plant light is an artificial light source, generally an electric light, designed to stimulate plant growth by emitting a light appropriate for

photosynthesis. Grow lights either attempt to provide a light spectrum similar to that of the sun, or to provide a spectrum that is more tailored to the needs of the plants being cultivated. The spectrum type, length, and intensity duration all play key roles in vegetative cultivation and overall plant health. The grow led panel is as shown in figure 10



Figure 10: The grow led panel

Intensity: Plants will grow tall, elongated stems without enough light because the plant is stretching to find additional energy rather than producing leaves to harness it. For indoor plants, this is not an option. Hence a light source of proper intensity has to be provided.

Duration: No plant requires 24-hour sunlight. Plants perform a fair amount of their vegetative growth during the dark hours, changes in the duration of a day affect flowering and fruit production. There should be preferred balance between light and dark which varies between species.

Spectrum: The color temperature of a light source is the temperature of an ideal black-body radiator that radiates light of comparable hue to that of the light source. Colors above 5000K are known as cool colors (blue) and closely resemble natural sunlight. Colors below 3000K are known as warm colors (red).

Water submersible dc pump: Submersible and jet pumps are the most commonly used pump types.



Figure 11: The water submersible dc pump

Submersible pumps illustrated in figure 11 push fluid to the surface as opposed to jet pumps having to pull fluids. Please check if only pure water is going through the pump. If the noise of the pump is not familiar or the water pressure is too low than air can be in the pipes. Air in the pipes can cause the pump to overheat. It is also good to know the water temperature to keep the motor safe from overheating.

Motor driver circuit: The simplest way to drive motor (or other load) is to use an N-Channel MOSFET in the low-side configuration. An N-FET starts to conduct when its gate voltage is higher than its source. Since the source is connected to ground, the gate can be driven with normal on-off logic. Schottky diode is used to protect against voltage spikes caused by the motor.

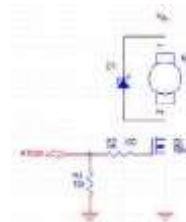


Figure 12: The motor drive circuit

Bluetooth module: It is used for many applications like wireless headset, game controllers, wireless mouse, wireless keyboard and many more consumer applications. It has range up to <100m which depends upon transmitter and receiver, atmosphere, geographic & urban conditions. It is IEEE 802.15.1 standardized protocol, through which one can build wireless personal area network. It uses frequency-hopping spread spectrum (FHSS) radio technology to send data over air. It uses serial communication to communicate with devices. It communicates with microcontroller using serial port(USART).



Figure 13: Bluetooth Module HC-05

1. Key/EN: It is used to bring Bluetooth module in AT commands mode. If Key/EN pin is set to high, then this module will work in command mode. Otherwise by default it is in data mode. The default baud rate of HC-05 in command mode is 38400bps and 9600bps in data mode. HC-05 module has two modes, data mode and command mode.
2. VCC: Connect 5V or 3.3V to this Pin.
3. GND: Ground Pin of module.
4. TXD: Transmit Serial data (wirelessly received data by bluetooth module transmitted out serially on TXD pin)
5. RXD: Receive data serially (received data will be transmitted wirelessly by Bluetooth module).
6. State: It tells whether module is connected or not.

Netpots: Net pots are used to anchor the plants in the system as shown in figure 14. It can be used with or without a grow medium. Net pots are often reusable and made from rigid plastic mesh to promote drainage and air circulation. Net pots have also been known to optimize root growth and plant development. Because of the holes that dot the sides of the pots, plants can easily acquire moisture and nutrients.



Figure 14: Net pots

Rock wool: Rock wool is made up of mineral wool. It is the most widely used medium in hydroponics as shown in figure 15. Rock wool is an inert substrate suitable for both run to waste and re-circulating systems.



Figure 15: Rock wool

Nutrient solution: The hydroponic nutrient solution consists of minerals in the raw water and nutrients added with fertilizers are shown in figure16. Minerals such as calcium, magnesium, sulphur and trace elements such as boron, manganese, iron and zinc may be present in the source water. Several important factors have to be considered when choosing fertilizers and preparing a hydroponic nutrient solution are water quality-salinity, concentration of potential harmful elements like sodium, chlorides and boron, required nutrients and their concentrations in the hydroponic nutrient solution is nutrient balance, the pH of the hydroponic nutrient solution and its effect on uptake of nutrients by plants.



Figure 16: Nutrient solution

II. Software requirements

The software is used to provide an interface between the user and the hardware. The hardware cannot work without the software in most of the embedded systems. Similar in this case where the system cannot work without software. Here, Arduino IDE, Raspberry, Python for controlling the some sensors through Arduino mini pro.

ARDUINO IDE: The Arduino integrated development environment (IDE) is a cross platform application (for Windows, macOS, Linux) that is written in the programming language java. It originated from the IDE for the languages Processing and Wiring. The arduino IDE supports the languages C and C++ using special rules of code structuring. The arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. The arduino IDE employs the program avr dude to convert the executable code into a text file in hexadecimal encoding that is loaded into the arduino board by a loader program in the board's firmware.

Sketch: A program written with the Arduino IDE is called a sketch. Sketches are saved on the development computer as text files with the file extension .ino. Arduino program consist of only two functions they are,

- **setup ():** This function is called once when a sketch starts after power-up or reset. It is used to initialize variables, input and output pin modes, and other libraries needed in the sketch.
- **loop ():** After setup has been called, function loop is executed repeatedly in the main program. It controls the board until the board is powered off or is reset.

RASPBERRY PI: The Raspberry Pi primarily uses Linux kernel-based operating systems. The ARM11 is based on version 6 of the ARM which is no longer supported by several popular versions of Linux, including Ubuntu. The install manager for Raspberry Pi is NOOBS. The Os included with NOOBS is Raspbian maintained independently of the

Foundation. Raspbian is compiled for the ARMv6 instruction set of the Raspberry Pi making it work but with slower performance. A minimum size of 2GB SDcard is required, but a 4GB SDcard or above is recommended. It supports almost all programming languages like C, C++, Python3.7, Javascript(node), Ruby, Lisp, Rust.

STEP BY STEP PROCEDURE

1. INSTALL RASPBERRY Pi

Step 1: Download the image

Official images for recommended operating systems are available to download from the Raspberry Pi website Downloads page. Alternative distributions are available from third-party vendors. The following zip tools support ZIP64 are 7-Zip (Windows), The UnArchiver (Mac), Unzip (Linux)

Step 2: Writing an image to the SD card

An image writing tool known as Etcher is used to install the image downloaded on to the SD card.

Etcher is a graphical SD card writing tool that works on Mac OS, Linux and Windows, and is the easiest option for most users. To write the image with Etcher: figure 17 shows the Etcher home page.



Figure 17:Etcher configuration window

Step 3: Insert the microSD card in your Pi and boot up Once the disc image has been written to the microSDcard, insert it into your Rasberry Pi, plug in the peripherals and power source. The current edition to raspbian will boot directly to the desktop.

Step 4: Booting process of Raspberry Pi

The raspberry Pi is booted using shell. The process is explained as follows

Connect to WLAN in GUI: Choose WiFi network and connect after connecting to a WLAN we need to find out the Pi's ip address. If the pi connects to the same router between boots, DHCP should give it the same ip. Static IP can be configured. Once the ip-address is obtained the Pi can be accessed with Putty. Putty is a open source terminal emulator, SSH and telnet client which help Raspberry Pi to get connected with another computer. Configuration of putty is shown in figure 18



Figure18: Putty configuration window

The default credentials are, (Password is not visible in Putty)
username : pi password : raspberry

Step 5: OS of the Raspberry Pi



Figure 19: Raspberry Pi window

After entering the required credentials the raspberry Pi OS opens where the desired operations to be performed on Pi can be done and edited.



Figure 20: Authentication window in firebase

Firebase: Firebase is a mobile and web application development platform developed by Firebase, Inc. in 2011, then acquired by Google in 2014. As of March 2020, the Firebase platform has 19 products, which are used by more than 1.5 million apps. In our projects we are using mainly three products shown in bellow.

Firebase authentication: Firebase Authentication is a service that can authenticate users using only client-side code. It supports social login providers facebook, GitHub, twitter and google. Additionally, it includes a user management system whereby developers can enable user authentication with email and password login stored with firebase. In our app we use the double authentication method. First are the email authentication for the safety and another phone authentication for the generating id.



Figure 21: Authentication window in firebase

Firebase real-time database: Firebase provides a real-time database and back-end as a service. The service provides application developers an API that allows application data to be synchronized across clients and stored on Firebase's cloud. The REST API uses the Server-Sent Events protocol, which is an API for creating HTTP connections for receiving push notifications from a server. Developers using the realtime database can secure their data by using the company's server-side-enforced security rules. We created the database for the storing the real time data and smooth operation with raspberry pi and the mobile application (app) the figure 22 shows the database structure.



Figure 22: Database structure

Store and sync data with Firebase NoSQL cloud database. Data is synced across all clients in realtime, and remains available when app goes offline. The firebase realtime database is a cloud-hosted database. Data is stored as JSON and synchronized in realtime to every connected client. Data is persisted locally, and even while offline, realtime events continue to fire, giving the end user a responsive experience. When the device regains connection, the real time database synchronizes the local data changes with the remote updates that occurred while the client was offline, merging any conflicts automatically. All firebase real time database data is stored as JSON objects. The database as a cloud-hosted JSON tree. Unlike a SQL database, there are no tables or records. When we add data to the JSON tree, it becomes a node in the existing JSON structure with an associated key.

RASPBERRY-PI and mobile application communication with database:

There are two important things that we have to think about while building our Automation System: security and reliability. In order to keep the system reliable we need to make sure that every time an action is performed, it is synchronized everywhere. In our raspberry pi ever fifteen minute once it will updated with database. In mobile app it will receives every time. Every morning eight'O clock raspberry pi receives data from database.

System design: The hardware system includes processor, sensors, and router to receive information through Wi-Fi. In this project Raspberry pi (ARM11 processor) is chosen to complete the core control. User's phone connected to the wireless internet to receive information through app to achieve real-time monitoring.

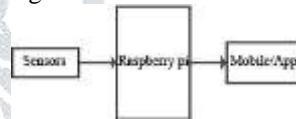


Figure 23: System design

Firebase machine learning: Machine learning is a mobile machine learning system for developers launched on May 8, 2018, in the google I/O 2018. Machine learning APIs feature a variety of features including optical character recognition, detecting faces, scanning barcodes, labeling images and recognizing landmarks. It is currently available for IOS or Android developers. The APIs can be used on-device or on-cloud. Machine learning is a mobile SDK that brings Google's machine learning expertise to Android and iOS apps in a powerful yet easy-to-use package. We can implement the functionality we need in just a few lines of code. There's no need to have deep knowledge of neural networks or model optimization to get started. In machine learning have the various types but here using Image labeling. We created custom image classification models from our own training data with AutoML Vision Edge. With ML Kit's image labeling APIs we can detect and extract information about entities in an image across a broad group of categories. The default image labeling model can identify general objects, places, activities, animal species, products, and more.

Assemble training data;

1. The images must be in one of the following formats: JPEG, PNG, GIF, BMP, ICO.

2. Each image must be 30MB or smaller. Note that AutoML Vision Edge down scales most images during preprocessing, so there's generally no accuracy benefit to providing very high resolution images.
3. Include at least 10 and preferably 100 or more, examples of each label.
4. Include multiple angles, resolutions, and backgrounds for each label.
5. The training data should be as close as possible to the data on which predictions are to be made.
6. The models generated by AutoML Vision Edge are optimized for photographs of objects in the real world.

Train the module:

1. Open the Machine Learning section of the firebase console. Select project when prompted.
 2. Click the AutoML tab, and then click create your first AutoML dataset or Add another dataset. After provide a name for the new dataset, the console will guide. When a model has high precision, it assigns labels incorrectly less often (fewer false positives). When find a score threshold that produces metrics you're comfortable with, make note of it; it will use the score threshold to configure the model in the app.
- Evaluate module:** When training completes, than can click the model on the dataset details page to see performance metrics for the model. In the context of image classification, precision is the ratio of the number of images that were correctly labeled to the number of images the model labeled given the selected.
- (a) Upload either the training images or a CSV file containing the Cloud Storage locations you uploaded them to. See Assemble your training data.
 - (b) After the upload completes, verify the training data and label any unlabeled images.
 - (c) Start training a model using the training data.

Publish/Download Model: If satisfied with the model's performance and use it in an app, publish the model, download the model, or both.

III. METHODOLOGY

Mechanism of temperature control: The first step is to provide an ideal temperature for the plant in order to have a healthy growth. The temperature monitoring and a regulating system is provided by a DHT22 temperature sensor and a 12V DC fan for sensing and maintaining the temperature respectively. The ideal temperature varies from plants to plants and type of the climatic conditions. For tomato, the ideal temperature is in the range of 22°C to 30°C. Initially, the 12V DC fan will be ON at constant speed to provide the exchange of gases between the shoot chamber and the external environment. If the temperature in the shoot temperature reaches above 31°C due to increase in outer temperature or due to excess respiration by plants. The speed of the fan will be increased to facilitate the cooling of the shoot chamber. The flow chart for the temperature monitoring and regulating system is as shown in figure 24



Figure 24: Mechanism of temperature control

Humidity monitoring (DHT22): Humidity control is one of the important factors which decide the growth of plants. The ideal temperature for aeroponics system is between 20°C and 25°C.

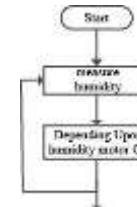


Figure 25: Humidity monitoring

And humidity should be around 70-80% of humidity and which gradually reduces around 40% humidity as plants mature. For humidity and temperature sensing and control, we use DTH22 sensor. It consists of a humidity sensing component and a NTC temperature sensor and an IC on the back side of the sensor. For measuring humidity they use the humidity sensing component which has two electrodes. The flow chart for the humidity monitoring is shown in figure25.

Mechanism of pump (230V): The mixture of water and pH solutions is present in water reservoir. These mixtures are sprayed to the root of the plant using nozzles and 230V water submersible pump at regular interval (60 second ON and 30 second OFF).



Figure 26: Mechanism of pump

pH solution monitoring and control: pH is one of the key factor which decides the healthy growth of plant. When the nutrient solution is added to the water of pH 7.0, its pH varies.

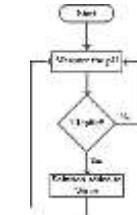


Figure 27: pH solution monitoring and control

The optimum pH that should be maintained for plants is between 7.4 and 9. If the pH increases beyond 9, the mixture of nutrient solution becomes acidic, hence the base solution is added to bring it to optimum range. When the pH decreases below 7.5, the mixture is basic, hence the acidic solution is used to bring it to optimum range.

Water level monitoring and control: When the water level is low in the reservoir, the pump gets ON for 5 sec to pump the water into the reservoir, and then the water level is made high. This is to ensure the proper mixing of the nutrient with water. The flow chart below figure 28 depicts the effect of water level.

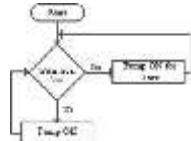


Figure 28: Water level monitoring and control

IV. RESULTS AND TESTS

Temperature monitoring and control result: If the temperature goes above 27°C, the speed of the fan will be increased until the temperature is brought back to the optimal value. The temperature value is displayed on the LCD as shown in figure 29



Figure 29: LCD showing temperature

Monitoring and controlling of humidity: The humidity levels of shoot chamber will be monitored regularly by DHT22 and the value will be displayed in the LCD as shown in figure 30.



Figure 30: LCD displaying controlling of humidity

Monitoring and controlling of pH: The pH values are monitored regularly and necessary action is taken to maintain Ph in the required optimal value of the plant in case variations. The pH value is displayed on the LCD as shown in figure 29 and figure 31 shows the Controlling state.



Figure 31: LCD displaying controlling of pH

Updating with database: In the raspberry pi, every fifteen minutes once the data will be collected, processed and updated to the realtime database. The "updating data" is displayed on the LCD as shown in figure 32



Figure 32: LCD displaying updating Database

Receiving from database: The raspberry pi, every morning eight O clock the data will be collected from the database. The "receiving data" is displayed on the LCD as shown in figure 33.



Figure 33: LCD displaying receiving data

Firebase database result display: All the values such as temperature, humidity, pH water level these values are sent to firebase database.



Figure 34: Results in firebase database

Mobile application communication with database: Our mobile application (app) called 'Aeroponics' is always synchronizing with firebase database. If any data change in the database immediately it will sync with our app. The figure 35 right side shows the Update in our app and left side updated feature in our app. These data's are already sync with our application.



Figure 35: Synced data app with database

Leaf disease detection result: The mobile camera captures the image of the leaf and process it's to detects any disease. If any present and indicates on the screen as shown in figure 36.

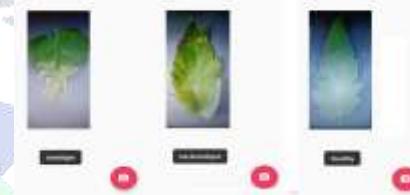


Figure 36: Two types of disease and Healthy leaf

Adding nutrients (NPK) to water: First we will add the Nitrogen to water and then Potassium then phosphorus. Figure 16 shows the adding NPK to water. After adding the NPK the LCD will shows like in the Figure 29 N = Nitrogen, P = Phosphorous, K = Potassium



Figure 37: LCD displaying adding N to the water



Figure 38: LCD displaying adding K to the water



Figure 39: LCD displaying adding P to the water

Conclusion

This paper has the potential to revolutionize the way humanity produces food both on the small and large scale. As the vision states, the project aims to create an open and accessible technology enabling everyone to grow food and to grow food

for everyone. However, revolution will not be the defining metric of success in the short term. Short term success boils down to achieving two important milestones. The first milestone is to create and demonstrate a functioning minimum viable product. This will right away prove or disprove the viability of the technology. This milestone also includes making available the plans, source code, and even purchasable kits of the minimum viable product in order to lower the barrier to entry for others to learn about and contribute to the project. This leads into the second milestone: creating a vibrant and excited community of skilled makers, hackers, and enthusiasts who will contribute to the development of the project.

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