system can create a revolution in field of Agricultural Industry.

I. LITERATURE REVIEW:

- The research is grounded in academic standards and advances the researcher's ideas; the related works used in this project are displayed in this part. The Internet of Things, or IOT, is now widely used in agriculture, and numerous studies have shown that using technology to help with agriculture may increase comfort and productivity.
- [6] : The system was able to handled conditions by Incorporating IOT technology along with necessary sensors. Titan Smartponics system controlled parameters through a web interface, and the results showed that the plants grown in the control system outperformed the external system.
- [7] The study done in this mainly focuses on bringing in the maximum productivity using much simpler.easier way of applying Internet of Things Concept to the traditional hydroponics system , Analysis was done on a single plant using a system comprising of pHarmbot, hydrobot to manage certain parameters
- [9] : The Project mainly focuses on optimizing power, water usage , using Soil moisture , DHT11 sensor and storing the collected data in a server database and developing front-end web apps to fetch the data which is more appropriate for growth of a particular sapling
- [11] : This project mainly deals with green house climate change and bringing in the maximum results with several sensors whilst manipulating climate , bringing variation in nutrient solution and other parameters
- [15] : The following work aims to include the concepts of Big Data and improvise their model by varying nutrient solution proportion and keeping track of them to achieve maximum yield.

II. OBJECTIVE :

- The main goals of this project are to create an automated hydroponic system that can be implemented by anyone from household garden applications to commercial farming to large-scale city planning models [6].

- The hydroponic system can be implemented where there is less supply of power and it can be achieved by using solar energy. The hydroponic system gives better yields rather than traditional soil-based farming.

- It requires a low cost for maintenance. Hydroponics will be long-lasting cultivation. With Installed sensors that send data constantly and sending updates/status in the form of notifications on the mobile application whenever the water supply runs out or when the motor turns on.

- It is also far less wasteful as the excess nutrient solution can be made to return to the supply,(also known as drip-system) bringing such concepts together with the hydroponics

III. METHODOLOGY

A. Hardware *:*

- DHT11 sensor: A temperature and humidity sensor as shown in (Fig 1.1) which measure the temperature and outputs temperature and humidity as the output. Sensor works on 3V to 5V voltage [16]. Light sensors are used to measure ambient light levels. For crops, light is the primary energy source for photosynthesis. When using a Light Dependent Resistor (LDR), remember that resistivity drops as light intensity rises and vice versa. The voltage divider circuit is made to detect resistance as a result of changes in light intensity. With a rise in light intensity, the voltage level rises. On the board, the analogue reading is taken. It is suitable for use in greenhouses [11] when artificial lighting is provided by any incandescent lamp [9].

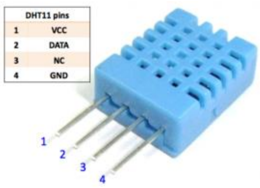


Fig. 1.1 DHT11 Sensor

- pH sensor: A sensors which measures the hydrogen ion concentration [7] in the water according to equation (1) [11].
- Water level depth sensor: A high level or drop recognition sensor which measures the volume of water (in cm^3) in order to determine the depth or the water level. So that we can find out the remaining water in the storage container and provide actual reports to avoid empty water containers which will result in hydroponic plants that will lack water [11]
- Water pump: Solenoid 2 valve Water pump which Pumps the water into the system when the depth of water reaches below a specified threshold value.
- Relay: A electromechanical switch which is used control water pump and controls movement of fan which is done through voltage switching. Relay Module is the electrical switch of mains voltage to turn on or off or let the current go through or not [9] and can be connected with ESP32 board as shown in (Fig. 1.2.)

Fig. 1.1. 4-Channel Relay module

- Fan : A device which works under relay which helps in regulating temperature of the system.
- Lights : A electronic device producing artificial light.
- Soil moisture sensor: A device which passes electric current through the soil and the observes resistance to measure the volumetric content of water [9].
- ESP32 microcontroller : It is one of the development board of Esp32 series . The module shown in (Fig. 3.1) which has built-in Wi-Fi connectivity and ability to drive the entire system through power allocation and is involved in sending data continuously [10].Other microcontroller boards such as Raspberry Pi can be used to store data in a cloud. Through IP address, the stored data can be accessed efficiently [15].

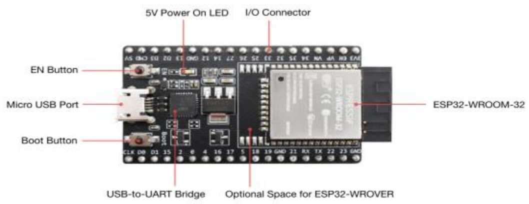


Fig. 3.1. ESP32 Devkit Module

B. ***Software*** *:* In order to enable functionality and resource heterogeneity, the suggested IOT software architecture must perform satisfactorily. Various software and application designs to perform analysis or to inform updates to user include the ones listed below :

- Arduino IDE: It is an open-source application that allows to code programs to ESP32 board and it runs on Windows, Mac OS X and Linux [10]. The ESP32 board with several data pins is easy for connecting various accessories .
- Thingspeak : A cloud platform which helps in remote monitoring of applications built over IOT and build matlab models perform analysis over the data.
- Blynk IOT: A mobile application which used control applications build over IOT via Internet . Provides user with the desired information through a graphical user interface or human machine intrface [16].

C. BLOCK DIAGRAM *:*

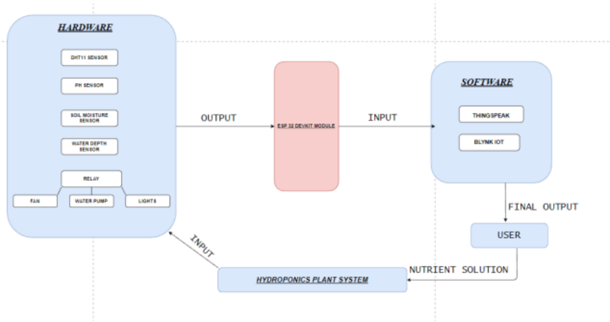


Fig. 3.2 Work-flow of the Model

D. APPROACH *:*

In the flow chart mentioned above (Fig. 3.2.), we can observe thatv a set of sensors are connected to ESP32 microcontroller through which data, analog pins are connected. We have used 2 breadboards which are powered by ESP32 board's (Fig. 3.1) positive,negative terminals , and these breadboards are used inturn to power up the sensors.

The compiled code will initially be run via uploading it to the ESP32 (Once uploaded, it will be saved until other code has been uploaded) Later, ESP32 is powered by a 12V battery or mains power source, which powers on all of the sensors and causes them to begin reading data from their interfaces and loading it into ESP32. The water level depth sensor is used in the first step of the process, reading the amount of water in the pipe (in cm3) and sending data back to the ESP32 [10], where the received value is compared with the threshold value that is given in the code. The motor is set to be switched ON through the relay if the value is less than the threshold., in which for every 2 seconds , it checks the status of the flag in the code and works accordingly , The same principle applies to the Temperature Sensor (DHT11), which measures temperature in Celsius and compares it to a predetermined threshold value. If the ambient temperature exceeds the threshold, the other relay condition is set to high, and the fan motor is switched on as a result (this comparison is made every two seconds).
It is possible to upload data from these sensors to Thingspeak cloud using the ESP32's built-in Wi-Fi function, where we did analysis, draw graphs to gather more information, and essential data that led to the plant's quick growth. Although any application can be constructed with sufficient technology, we were able to connect this data with the Blynk-IoT mobile application. Although any application can be created with a suitable front-end [9] thanks to the Bluetooth feature of the ESP32, certain notifications were sent to users' mobile devices and for some sensors, it was possible for them to remotely control the operation of the system with a stable network connection [6].

APPLICATIONS

Smart Hydroponics system has a variety of applications. Right from harvesting plants in lands to cultivating the same in space stations, these have major applications.

By Combining the known Concepts of IoT and traditional farming approaches we can come up with a smart system.

Organic Farming has been a main focus of interest nowadays, Recently In some parts of Southeast Asian Countries, Restaurants in subways used hydroponics to produce their food in particular lettuce [17] and use the same. So by installing such a system can actually improve their performance.

It can be used in many buildings, and terrace farming as it requires minim space ensuring a healthy environment, it can be implemented in space stations, where the grown food can act as a source of food for astronauts.

It can be used alongside with aquaponic which is eco-friendly and sustainable [16].

IV. Results and Discussions

The entire working Model was prepared according to the approach discussed earlier which followed drip system to provide solution efficiently [7]. To test the model , We experimented by having 2 sets of plants [6].One of the set included some of the grown pre-mature plants namely tomato, coriander, lettuce [7] and allowing the same to be grown i.In the Other sample same set of plants which were being grown in normal environment (without using developed system)were included. We left the model to work on its own for about a week, and these were some of the data that we obtained in ThingSpeak using which we plotted some of the parameters like temperature variation, water consumption, etc. We even recorded plant's growth height on a daily basis and here are some of the Analysis that's been done using Matlab Analysis Tool.

A. Discrete sequence Plots

1) Variation in solution's pH:

Different nutrient solutions are more effective on certain hydroponics systems. On the other hand, because different nutrient solutions breakdown into ions in ions, they give varied conductivity values.

The ability of plants to absorb solutions typically depends on the pH of the solution [7]. Plants absorb nutritional solutions through their roots. Acid solutions, for instance, encourage the absorption of hydrogen, the pH value can be found as mentioned in equation (1) [11]:

$$pH = -\log[H3O+] \qquad (1)$$

We looked into data collected from thingspeak cloud which contained 4000 data points taken across 2 days. At first, the nutrient solution which needs to be rich in nutrient elements [11] will be acidic because of the presence of Nitrogen, Phosphorous, and Sodium (also known as NPK) .At first as the water supply starts water tries to neutralize the solution hence the value of pH goes on increasing because of more water content [6]. After a Certain Point when the threshold value is reached, supply stops and that's where a gap can be observed in (Fig. 7.1) in the graph, later when plants start to absorb the solution and hence water content goes on decreasing, and the presence of NPK dominates so pH gradually decreases. And this process goes on as and when water needs to be pumped.

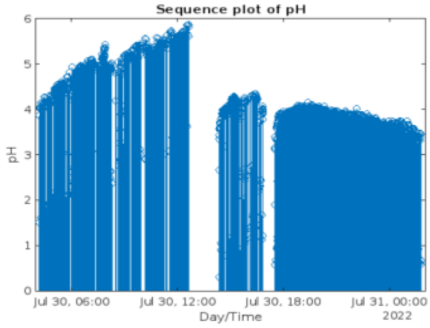


Fig. 7.1. Sequence Plot of pH

2) Variation in Water Level:

It is one of base condition for maintaining supply of solution .Initially, the threshold is set to 2500 cm^3 So whenever the water supply reaches the threshold value the supply stops by turning motor off, and when water is being consumed (level goes down), then water supply begins by turning motor on, thereby maintaining an average threshold. The same can be seen in (Fig. 7.2) where alternate data points are observed going in up, down trend.

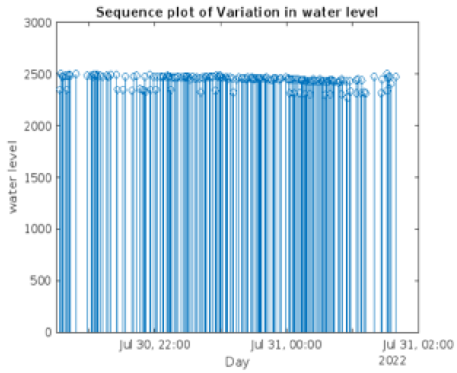


Fig. 7.2. Sequence plot of water level (in cm^3)

B. Histograms :

1) Temperature variation:

The graph (Fig. 7.3) showcases plot of histogram wherein data is taken over 72 hours is been depicted on the y-axis (across 3 days), and the temperature scale is depicted on the x-axis, We can observe that, in the first 10 hours maximum temperature of 26 degrees was observed and in the next 10 hours, it has increased to 26.5 degrees on average and so on.

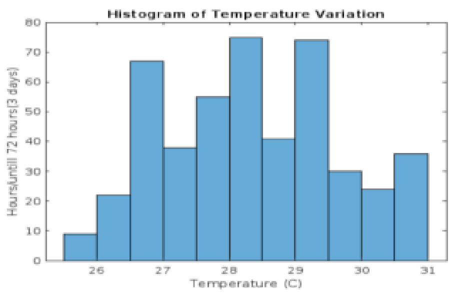


Fig. 7.3. Variation in Temperature (C)

2) Variation in Soil moisture Content:

The graph (Fig. 7.4) showcases plot of histogram which depicts data which was collected for around 83 hours (3+ days). Although soil is not used in the project, the cocopeat soil was used only to give support for the growth of plants. Hence when the presence of solution in the tank, interacts with this soil and hence we were able to monitor soil moisture. We can observe up-down trend which depicts the usage of solution by plants every now and then.

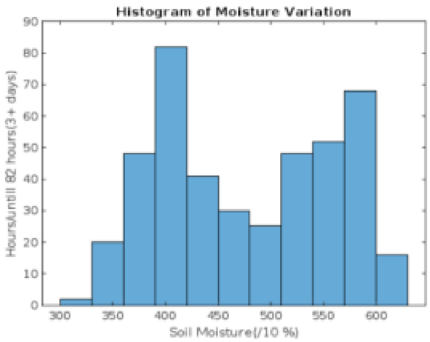


Fig. 7.4. Variation in Soil moisture (in relative %)

C. Two Y-Axes Plot:

These plots are helpful in identifying underlying relationship , pattern observed among any 2 given parameters

1) Temperature against pH:

From the graph (Fig. 7.5) It is evident that, Initially, whenever the Temperature(represented in blue color) was observed to be more, plants consumed more of the solution and a bit of evaporation in solution can be expected, and hence the value of the solution's pH(represented in Red color) can be observed bit higher [6], this can be attributed due to the fact that more of water content was consumed leaving NPK behind and resulting in a solution which is highly acidic nature.

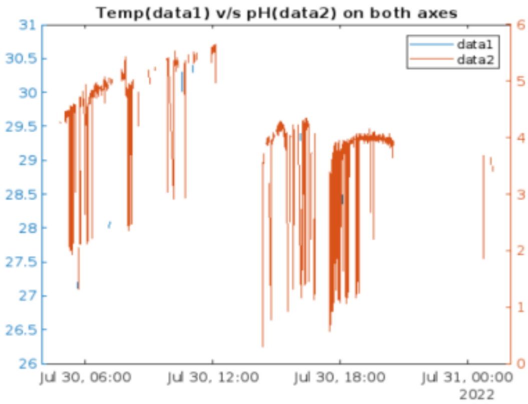


Fig. 7.5. Temperature v/s pH (Temperature, C)

D. 2-D Line Plot*:*

1) Measure of variation in pH *:*

The graph (7.6) indicates that , Initially on providing the solution, water content gradually increases. Hence an increase in pH is observed as the presence of NPK is neutralized , later as the solution is consumed by plants, pH gradually decreases, this can be attributed due to low watery content and higher nutrient concentration(NPK), hence the solution is more acidic which indicates less pH value observed in Right hand side of graph(Fig. 7.6).

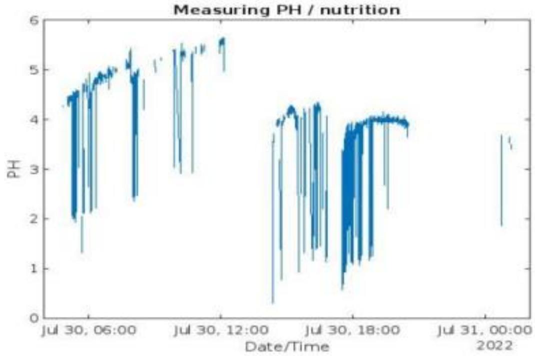


Fig. 7.6. Variation in pH across two days

E. Growth Rate Results:

From the growth chart (Fig. 7.7) and (Fig. 7.8) it is evident that by applying principles of IoT one can expect a good, fast yield compared to the traditional approach. By automizing the entire process not only we can reduce human involvement but also can get the expected product in a much easier, faster way. In these charts we can see linear growth trend across 7 days , The red line indicates Growth rate of plant using 1st sample which had plants that were grown in system and blue line indicates those plants that were grown in traditional hydroponics approach. Here we have considered plant's height measurement as one of the qualitative measurement which determines successful growth of plant which implies rapid growth in plants.

Under varied conditions, plants were hydroponically cultivated, and some of morphological data were measured and analysed. the blue light LED -treated plants Greater accumulation of biomass, leaf density, leaf area, and pigment content were the results of additional LED light [17].

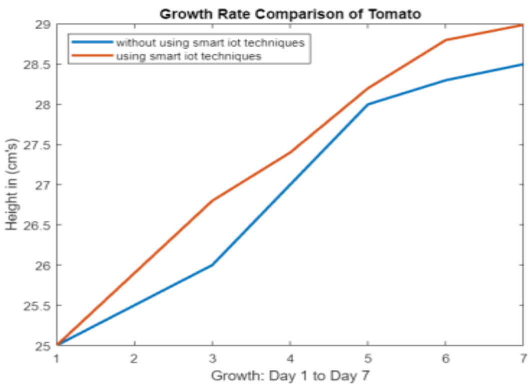


Fig. 7.7. Growth rate of Tomato (in cm)

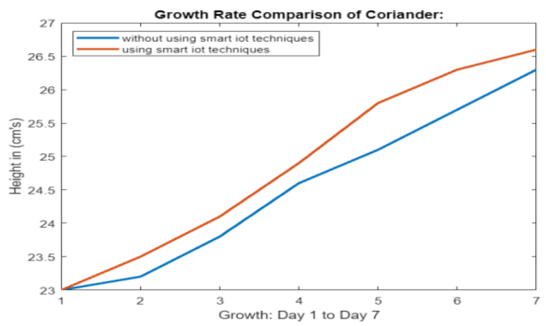


Fig. 7.8. Growth rate of Corriander (in cm)

TABLE I. Growth rate Comparison of Plants with and without using IoT Techniques :

Plants Variant (Type)	Height With Traditional Approach In 7 days (in cm)	Obtained pH Range	Obtained Temperat--ure Range (in Celsius)	Height achieved With IoT Approach In 7 days (in cm)
Tomato	28.6	4.9-5.6	21-26°C	29
Lettuce	18.5	5.2-6	21-24°C	18.8
Coriander	26.2	4.9-6.3	25-30°C	26.6

From the Above Growth Comparison of various plants (TABLE I.), we can observe that ,By using smart Hydroponics system ,the yield of plants increases when compared to the conventional method of growing Plants. This Table (TABLE I.) also shows the optimal conditions of growing plants (parameters like temperature) [16] (like lettuce, tomato coriander) which we attained for fast/successful growth under this system. We can observe that for that particular range of pH, Temperature [9], variation in height of the plants.

F. MOBILE APPLICATION :

Since our system uses ESP32-Devkit which has built-in Wi-Fi module , it is possible to send the status of the system and necessary data into the thingspeak cloud as well as the Blynk-IoT [16] mobile application [9] wherein the user is notified with appropriate messages and also notifies about the actions that need to be taken. For example, the below table (TABLE II) shows some notifications that we got while experimenting according to the scenario of system:

TABLE II. User Notifications

Condition/status of the system	**Notification through App**
Water level (<2500)	Low Plant Water level
Temperature (>25 degrees)	Fan turned ON.
the Motor is ON/OFF	Motor ON / OFF
The Ph of supply below a set threshold	Supply Improper

V. CONCLUSION

- Hydroponics is trending around the world as a viable and feasible alternative to various other techniques of growing plants for all the right reasons.
- The better yield of plants is a very attractive feature for farmers around the globe to implement this system. Soilless cultivation of plants is extremely useful in urban household gardens and other places where availability of land is scarce.
- Integrating Hydroponics system with IoT Principles increases the effect of these advantages and also provides an easy-to-operate interface to look at and manage the system without much of human intervention.
- The automated system thus developed can be powered by Solar Energy so that we can harness natural resources and make the system eco-friendly [17].
- Cholorophyll enriched plants can be grown upon successful usage of appropriate LED's which would exihibit better growth and enabling superior absorption of light for photosynthesis [17].

A. Some of the Major advantages includes:

1. We can have full control over nutrients by constant monitoring by the system, and it takes up 15% less space to grow as we can perform Vertical Farming, Drip irrigation Hydroponic system [15] Cultivation which saves water, resources.
2. Since roots of plants will be always in contact with nutrient solution , growth rate of the plant increases rapidly compared to traditional approach.
3. The system developed is User friendly which requires no prior knowledge about the working system.
4. In a challenging setting, hydroponic farming will be helpful because rapid growth of plants can occur in remote areas like arid desert, underwater(oceanic farming)[7].
5. Since data is stored in the cloud, analysis can be made to figure out the most optimal conditions to grow a certain plant [8].

VI. FUTURE SCOPE

- With the help of various sensors, bulk amount of data can be collected and various sorts of analysis can be done to bring out results and parameters which can improve the conditions and production of the hydroponic system ,by monitoring the system by knowing IP address to access the Dashboard[15].

- In the mindset of the growing population, the self-sufficient system can be introduced to create a hydroponics farm system to cover all the waste place in creating a local hydroponic environment which reduces the dependence on other systems.

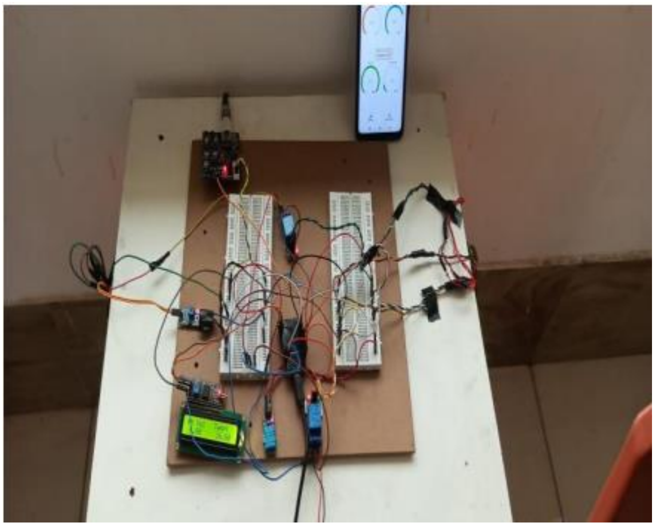
- Moving Further , Ultra-Violet (UV) based LED lights can be used to harness adequate amount of light energy being supplied to plants appropriately [17].

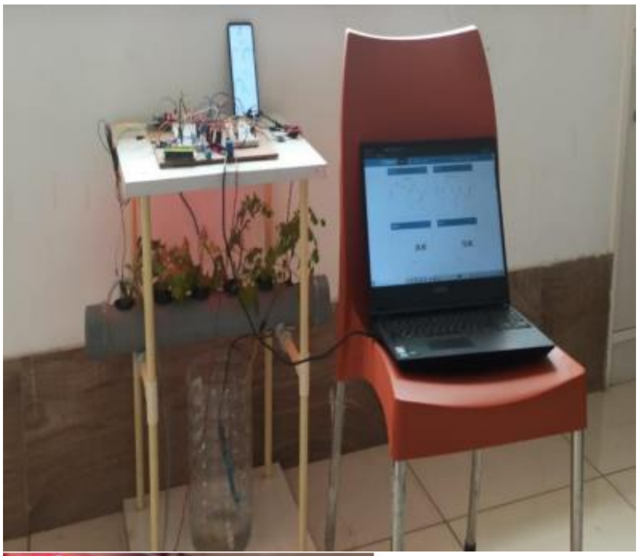
- Installation of Insecticides solution spray can be included right above the plants to ensure the quality of yield

- We can even ensure that more of Carbon-dioxide can be supplied to the plants by passing through various membranes, which can act as Air-Filter

- With large amount of data being gathered Certain concepts of Big data [8][15] can be applied to process these and concepts of Machine Intelligence can be applied to know the quality, quantity of yield.

- Aquaponic system can be implemented Without utilising any agricultural pesticides, aquaponics farming is an exceptionally productive way to raise organic fruits, vegetables, greens, and herbs with the added benefit of fresh fish as a healthy, sustainable protein source.





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