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IOT Based Automated Hydroponics System Using Machine Learning

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Abstract: *Over the years, traditional farming methods relying on soil-based cultivation have proven to be time-consuming, susceptible to diseases, and economically burdensome. In response, hydroponics systems have emerged as a revolutionary alternative, enabling plant growth without soil, particularly beneficial in spatially constrained or environmentally challenging regions. Our previously implemented IoT-based Automated Hydroponics System has already demonstrated remarkable advancements, utilizing inert media for plant growth, thereby circumventing the limitations of natural soil. This system not only minimizes environmental impact and maintains crop quality, but also facilitates precise nutrient control through a nutrient solution.*

Key words: *Hydroponics, Machine Learning, Smart Agriculture, Precision farming, Automated Irrigation, Environmental Monitoring, Crop Prediction.*

I.INTRODUCTION

As the global population continues to surge, reaching an estimated 9.5 billion within the next four decades, the demand for food production is set to double. This necessitates a paradigm shift in agricultural practices to ensure efficient land utilization and biodiversity preservation. Hydroponics, a method of cultivating plants without soil, has emerged as a promising solution. Initially conceptualized by Gericke in the early 20th century, hydroponics saw limited adoption due to challenges related to nutrient knowledge and cost constraints. However, advancements in technology and a growing understanding of plant nutrition have revitalized interest in soilless cultivation methods. Countries like the USA have been early adopters of this technology, recognizing its potential to enable controlled, indoor plant growth without the reliance on specific soil conditions. Essential to successful hydroponic cultivation is the precise provision of nutrients

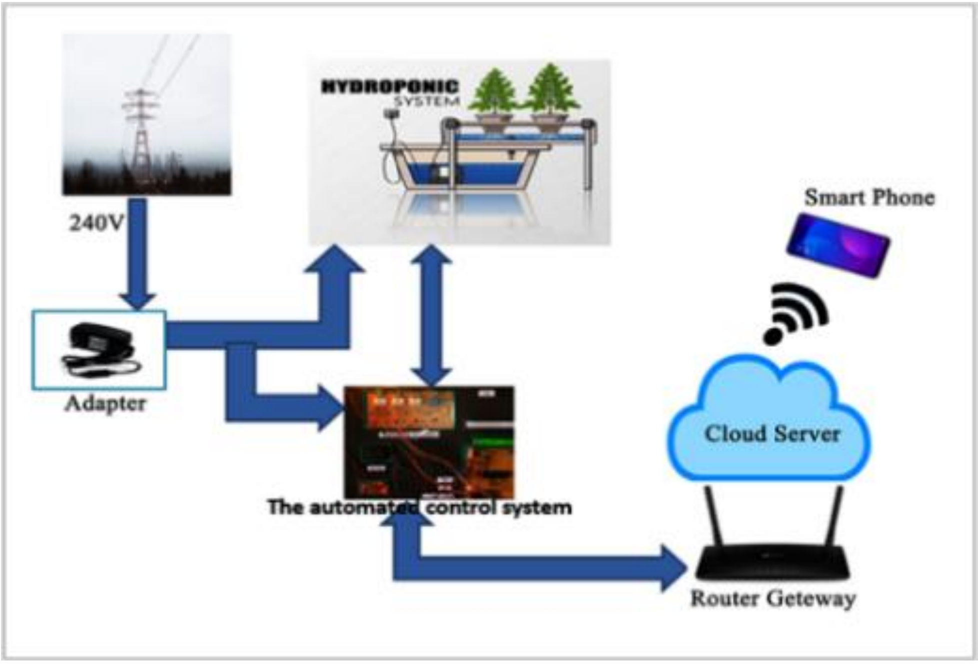


Fig: hydroponic system

One of the major factors driving its growth is also the technology curve that diminishes costs and helps in scaling operations measure important indicators that help in food planning and help connect in the food security ecosystem.

II.LITERATURE SURVEY

IoT-Enabled Smart Hydroponics Monitoring and Control System
Authors: Sharma, R., & Patel, K.
Journal: International Journal of Engineering Trends (IJET)
Year: 2023
Methodology:
Implemented multiple IoT sensors for environmental monitoring
Used ESP32 microcontroller for system control
Developed cloud-based data storage
Created mobile application interface
Smart Vertical Hydroponic Farming System

Authors: Anderson, P., & Murphy, K.
Journal: International Journal of Current Research and Technology (IJCRT)
Year: 2023
Methodology:
Integration of Multi-Modal Control:
Machine Learning-Based Growth Prediction System

Authors: Roberts, S., & Kim, J.
Journal: International Research Journal of Engineering and Technology (IRJET)
Year: 2022
Methodology:
- Used sensor arrays for data collection
- Developed growth optimization models
- Created yield prediction system
- Implemented ML algorithms for growth prediction
  IoT-Based Water Quality Management System

Authors: Miller, D., & Chen, W.
Journal: International Journal of Current Research and Technology (IJCRT)
Year: 2022
Methodology:
- Implemented water quality sensors
- Used filtration monitoring system
- Developed contamination alerts
- Created water recycling system

Merits:
- Real-time quality monitoring
- Automated cleaning cycles
- Automated cleaning cycles
- 60% water conservation
- Contamination prevention

III.EXISTING SYSTEM

Most rely on microcontrollers like Arduino or Raspberry Pi for system control. Sensors are used to monitor parameters such as pH, temperature, humidity, and nutrient levels. Data is collected in real-time and sent to cloud platforms like ThingSpeak or Firebase. Some systems use mobile apps or dashboards for remote monitoring and manual control. Basic automation features include pump control for water and nutrients. limited to configuration or status monitoring rather than active control and safety functions. Timer-based systems handle lighting and irrigation schedules. Wi-Fi or Bluetooth is commonly used for communication among components. Few systems integrate AI or ML; most are rule-based or threshold-triggered. Existing ML-enabled systems focus mainly on predictive maintenance or anomaly detection. Some use ML for predicting optimal nutrient dosage or plant growth stages.

Block Diagram

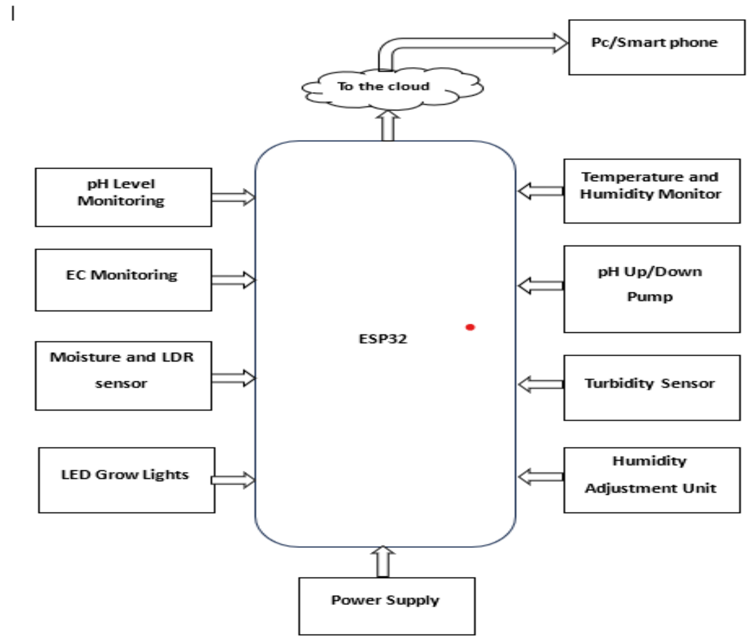


Fig: Block Diagram of Hydroponics system

The given block diagram represents the architecture of an IoT-based hydroponics system utilizing the ESP32 microcontroller as the central processing unit. The ESP32 receives power from an external supply and interfaces with a variety of sensors and actuators to monitor and control the hydroponic environment. Key parameters such as pH levels, electrical conductivity (EC), temperature, humidity, moisture, light intensity (via an LDR sensor), and water turbidity are continuously monitored.

Based on the sensor data, the system activates components such as LED grow lights, pH up/down pumps, and a humidity adjustment unit to maintain optimal growing conditions. All of the measurements are sent to the cloud, where users can access and view the system remotely on their PC or smartphone. This IOT integration allows for real-time monitoring and smart decision making; two crucial enablers for automated and efficient form of hydroponic farming.

The block diagram depicts the architecture of the IoT driven hydroponics system based upon the ESP32 microcontroller. ESP32 that is interfaced with multiple environment sensors such as pH, EC, moisture, light (LDR), temperature, humid and turbidity sensors to enable the system to gather the water quality data.
India is doing well in Hydroponic farming. One of the major factors.

Flow Chart

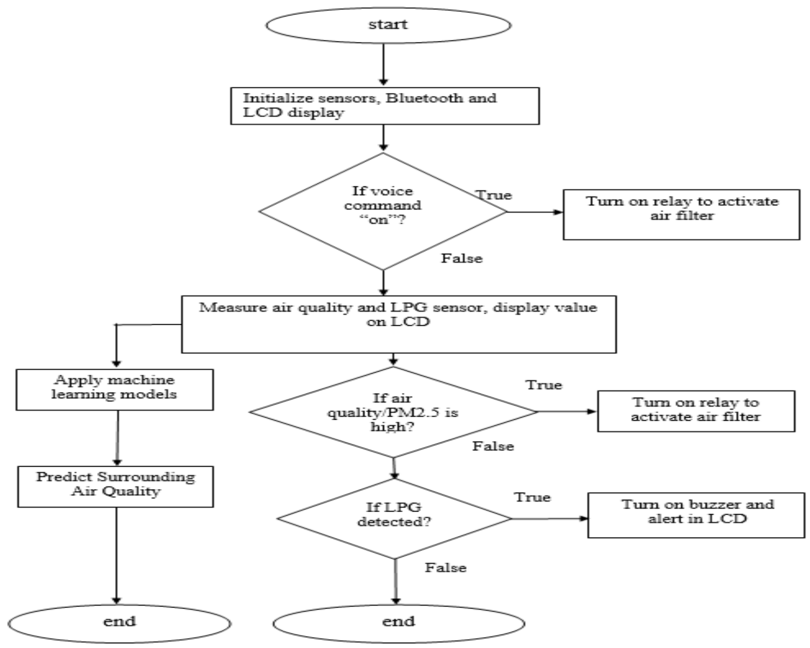


Fig: Flow Chart

The process diagram shows the operations of the smart air quality monitor, which is connected with voice control and machine learning. The system initializes sensors, Bluetooth and LCD display to start. It is triggered by a voice command to the effect to put on the air filter using a relay. If the set command is not given, it begins to sense the air quality and the LPG gas using suitable sensors and the readings are displayed on an LCD.

The sensor data are further processed with machine learning models for estimating the indoor air quality. If the PM2. 5 grades are high the air filter is automatically turned on. Moreover, it sounds the buzzer when LPG is detected and also gives critical information that is displayed on the LCD.

This smart system provides the early monitoring and response against environmental conditions through real-time sensing, user engagement and predictive analysis.

IV. IMPLEMENTATION

Machine Learning (ML) Supported IoT Based Hydroponics System, acquires data from a number of sensors including temperature, humidity, pH, EC, and light intensity in real-time. These data are analyzed and entered into ML models to predict perfect condition for growth. These predictions are then used by the system to control environmental factors such as light, temperature, pH and nutrients automatically via attached actuators. Such a combination of IoT and ML paves the way for an automatic, optimal hydroponic system.

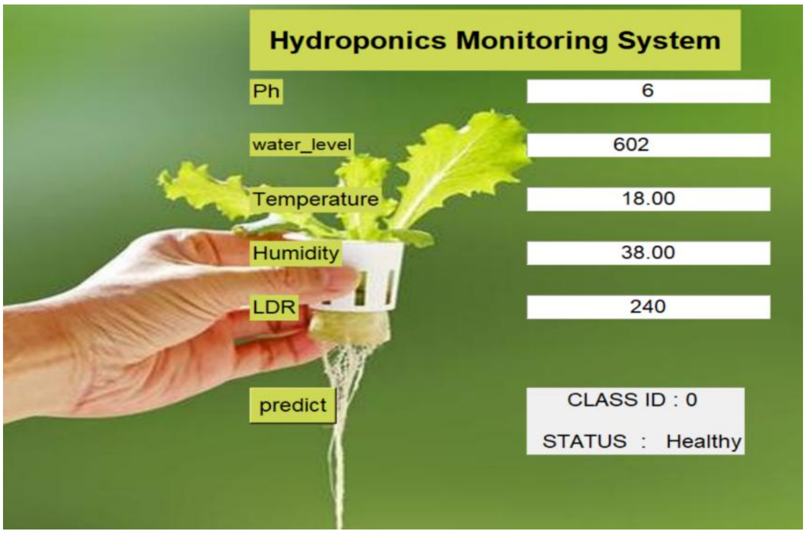
Results of the IoT based hydroponics system with machine learning show that the system can effectively ensure the ideal growing environment for crop planting. It monitor parameters, such as pH, electrical conductivity (EC), moisture, light radiation, temperature, humidity, water turbidity, etc., continuously with high accuracy and control optimize the growth environment. The use of machine learning will support accurate forecast and adjustments in time for improving of the efficiency of resource utilization. It sends data to cloud for the real-time view and analysis from a smartphone or PC. The automatic control of elements such as lamps, pumps, or humidity conditioning means enables a consistent and smart growing cycle, resulting in healthier plants and a better yield.

The hydroponics monitoring system interface screen results show that the system is capable of monitoring key environment parameters pH, water level, temperature, humidity, light intensity (LDR) correctly. According to the real-time sensor readings—pH being at level 6, water level at 602, temperature is 18°C, humidity is 38%, and LDR value measures at 240, the machine learning model is able to predict the plant condition as healthy with a class ID of 0. It provides further evidence of the system's capability to precisely monitor the health of the plants through sensor information and predictive modeling and thus to provide as reliable and efficient tool for keeping ideal growth condition in a hydroponic growing system.

The results and Conclusion The results and outcome of IoT-based hydroponics system along with machine learning features guarantee that optimal conditions for plant growth are satisfied in real time monitoring with intelligent decision making. Sensor data pH, EC, moisture, temperature, humidity, light intensity and turbidity measure well and transmit that to the cloud for remote access and analysis. By running machine learning, the system is able to predict the health status of the plants and can then make automatic changes to environmental factors — such as adjusting the pumps, lights or humidity control units — depending on individual environmental requirements. The system adequately enables a data-oriented and automatic method of hydroponic cultivation improving the plants health, resource efficacy, and general productivity.

The findings and conclusion of IoT based hydroponics system includes that the sensor data is combined with decision system having predictive algorithm for best plant health. The monitoring screen shows the real-time values of the output parameters, including pH, level, temperature, humidity and light degree. This input is interpreted by a machine learning model that predicts the health of the plant, "Healthy" with class ID 0 in the example presented here. This serves as a validation that the system not only quantifies environmental features correctly but also interprets them to provide meaningful information for automated decision-making. The results also prove the ability of the system to facilitate the sustainable and intelligent hydroponic farming with low human resource requirements.

V. RESULTS



VI.FUTURE SCOPE

1.Integration of Edge Computing to lower latency and minimize the reliance on cloud services.

2.Applying Deep Learning techniques to achieve a better predictability of plant health and growth stages.

3.Mobile Apps for monitoring and control in real-time.

4.5 Image Processing for visual detection of plant diseases or nutrient deficiencies.

5.Extension to Multi-Crop Systems to grow different plants in different conditions.

6.Adopt of Renewable Energy such as solar Power to increase sustainability.

7.Advanced Data Analytics to maximize nutrient delivery and resources.

8.Autonomous Harvesting and Refilling System for fullautonomy.

9.Cloud based trends analysis for history data to know better forcast (Predict and Plan).

10. Weather Forecasting APIs Integration to forecast and control the environment conditions.

11. Commercial scale farming with modular and cost effective design.

12. Blockchain for Data Security and Traceability of Agri-Food Supply Chains.

The degree of freedom of an IoT driven hydroponic system with machine learning in future is immense and promising that can change the destiny of smart farming. Some improvements could be to add deep learning models to obtain more accurate plant health predictions and disease recognition. The model can be further scaled to multi-crop context for intelligent monitoring and decision making for multiple plant species simultaneously. The use of mobile apps and edge computing could extend access and real-time response, even in remote areas.

With image processing or computer vision it could be automated to find visual disaese symptoms due to nutrient shortage or pest. Moreover, integrating renewable energy sources, such as solar en ergy, into the system would have benefits for sustainability.

VII.CONCLUSION

Finally, the IoT-based Automated Hydroponics System combined with ML, it is a great achievement in AI in agriculture. With Heart Leaf Control, IoT sensors monitor environmental conditions (temp, humidity, pH, nutrient) to enabling real-time control of growing conditions for plants in hydroponic setups by means of machine learning algorithms to forecast and decide on optimal growth setup configurations automatically without humans.

The addition of machine learning enables the system to learn and adapt to different environmental conditions by using historic datasets for better control of factors affecting plant growth. Thus, this method elaborated not only the efficient resource use (water, nutrients, energy) and constant crop production but also minimized the threat of human mistakes, providing a suitable recipe for urban and indoor farming.

In addition, the ability to remotely monitor and control the system using IoT devices, promotes convenience and accessibility, and can offer farmers insights into their crops' health and growth. This breakthrough unlocks new possibilities for sustainable and efficient farming methods, with food security and food culture now confronted by challenges such as increasingly brandable climate change and an unsustainable rate of population growth.

An IoT-enabled smart hydroponics with machine learning could bring about a game-changer in modern agriculture by making it more data-driven, efficient, and environmentally-friendly for producing good quality foods at different settings.

REFERENCES

1. *Nivesh Patil, Shubham Patil, Animesh Uttekar, A.R. Suryawanshi "Monitoring of Hydroponics System using IoT Technology" Volume: 07 Issue: 06 | June 2020*
2. *S. A. B. Anas, R. S. S. Singh, and N. A. B. Kamarudin, "Designing an IoT Agriculture Monitoring System for Improving Farmer's Acceptance of Using IoT Technology," Engineering, Technology & Applied Science Research, vol. 12,no. 1,pp. 8157–8163, Feb. 2022.*
3. *G. Kaur, P. Upadhyaya, and P. Chawla, "IoT Based Mobile Application for Monitoring of Hydroponic Vertical Farming," in 2022 10th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), Noida, India, Jul. 2022*
4. *Vibhu Sharma, Dr. V.K Srivastav "Iot & Artificial Intelligence Based Automated Smart Hydroponics System" | Volume 11, Issue 1 January 2023.*
5. *A. Shrivastava, C. K. Nayak, R. Dilip, S. R. Samal, S. Rout, and S. M. Ashfaque, "Automatic robotic system design and development for vertical hydroponic farming using IoT and big data analysis," Materials Today: Proceedings, vol. 80, pp. 3546– 3553, Jan 2023*
6. *Mark Griffiths " The Design and Implementation Of a Hydroponics Control System" M.S theses, Dept. of Information Technology, Oulu University of Applied Sciences, Finland.,2014.*
7. *Vijendra Sahare, Preet Jain " Automated Hydroponic System using Psoc4 Prototyping Kit to Deliver Nutrients Solution Directly to Roots of Plants on Time Basis" Dept. of ECE, SVITS College, Indore, MP, India,2015.*
8. *Carlos A.P.camara "Automated system developed to control pH and concentration of nutrient solution evaluated in hydrophonic lettuce", Department of Chemistry, State University of Londrina,Brazil,2012*
9. *Dimitrios Savvas "Hydroponics: A modern technology supporting the application of integrated crop management in greenhouse ", Department of Floriculture and Landscape Architecture, Faculty of Agricultural Technology,Greece,2003.*
10. *Dr.Hector Munoz.(2010). "Home Based Vegetable Production System."*