An Insight on Artificial Intelligence (AI) and Internet of things (IOT) driven Hydroponics farming

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Abstract-The nation's economy and prosperity are substantially impacted by agriculture as food is the necessity for human beings. The aim of this study is to solve the issue like shortage of quality foods especially horticultural crops that are essential for our healthy lifestyle. The practices of modern farming that includes soil-less cultivation can be an alternate way to overcome the problems that farmers are facing in traditional way execution of insightful hydroponics system that uses Artificial Intelligence (AI) and Internet of Things (IoT). Factors like pH of nutrient solution, CO_2, light, temperature, relative humidity, Electrical Conductivity (EC) can be monitored on daily basis using advance sensors in hydroponic system for efficient utilization of our precious natural resources that leads to sustainable agriculture to meet out the future demand of agriculture commodities.

Key Words: Hydroponic technique, Artificial-intelligence, Internet of Things, Automated agriculture, Deep Learning convolutional neural network.

1. Introduction

The projected growth in world populations is expected to trigger approximately 63% surge in agricultural demand by the year 2050. The new innovations that can effectively revolutionize the agriculture sector to address the global food challenge by narrowing the disparity between food supply demands are the need of this hours. In this manuscript, the focus is on the development and design of a system that is based on the Internet of Things (IoT) and an Artificial intelligence (AI) mechanism that can effectively manage various factors in a hydroponics system. The variables like pH, water inflow and outflow, humidity, carbon dioxide, electrical conductivity and nutrient solution intake. The prime objective of this study is to address the significance of hydroponic system, which offers a soil-less method to cultivate the variety of agriculture commodities in fully controlled system. This system will also be beneficial for people who live in apartments and overcrowded urban areas, where soil-based cultivation may not be possible. The most interesting fact is that NASA is extensively working on hydroponics which have future to explore to Mars and

moon, which play a critical role in in reshaping the space exploration and it will very benefit to the Astronauts [2]. Hydroponics proves the proficient solution for food cultivations in the adverse and challenging environment conditions like deserts, mountains region [4]. There is a need of 2 to 3 times more food in the future as result of rapid population growth across the world because each living entity need food for their survival in the earth. Hydroponic is a soilless method of plant cultivation, where crops grow in water that comprise of essential Plant nutrients and other components required by plants for their growths. This becomes more effective and productive by integrating the Internet of Things (IOT), Artificial Intelligence (AI) and machine learning (ML). Hydroponics heavily rely on maintaining specific environmental conditions such as pH level, air temperature, humidity, nutrients EC. Neural networks like DNN are a sub-part of AI which are used in automating tasks for hydroponic cultivation. Moreover, system designs like IOT and AI will help in continuously monitoring these factors, ensuring their defined ranges. The foundation component within deep neural network incorporates a fundamental building block known as the perceptron, which was originally conceived during the 1960s.[1-5]

2. Problem statement

The complexity of technologies like AI and IoT in agriculture demands expertise from cultivators who need to operate both agricultural and technological aspects [11]. The initial investment cost for implementing advanced technology, infrastructure, and automation systems for crop growth is high, despite the potential for higher returns [2]. Many IoT systems, particularly in agriculture, exhibit high power usage, resulting in increased energy costs [14]. AI and IoT technologies in agriculture can be challenging due to their complexity, additionally, poor sensor data quality (DQ) negatively impacts the performance of models [11]. In different climates and crops, DNN models need to be robust and adaptable over time intervals due to varying conditions. DLCNN models are particularly prone to over fitting because of limited data. Incomplete or limited data (DC) further complicates the development of deep neural network (DNN) models [2].Hydroponics presents its own set of challenges, including the continuous task of monitoring and adjusting nutrient levels [6]. Algae growth in nutrient-rich hydroponic solutions can lead to clogs and competition for nutrients, and pH fluctuations impact nutrient uptake by plants. Learning to optimize a hydroponic system takes time due to its learning curve in successful hydroponic farming. The agricultural sector contends with climate variability, necessitating the development of robust DNN models (R) [10]. Ensuring accuracy in data analysis involves utilizing cloud-based storage, Raspberry Pi, and AI-powered analytical tools (DA = Cloud Storage + Raspberry Pi + AI Tools). To enhance disease and pest detection, AI-based camera sensors are implemented (DD = AI-Camera) [23]. This comprehensive approach aims to address the challenges posed by the intricate nature of AI and IoT technologies in agriculture. Deep Learning Convolutional Neural Network (DLCNN) models face a common issue called over fitting, which means they may become too specialized and less adaptable to new data (OF = Likely). To enhance disease and pest detection, an AI-based camera system is implemented (DD = AI-Camera). However, there's a constraint on hardware resources available for DNN models, quantified as limited resource availability (RA).[6-10]

3. Review of literature

In the recent times, there is eminent significance in the integration of technology into agriculture, with the precise use of IOT, AI and MI [1]. Several researchers have drawn outcomes from their work and study, state that plants could absorb and utilize nutrient from

the given water-soluble nutrient solution as a result it was observed that soil is not mandatory to grow plants [13]. Hence plants can be foster on the natural or artificial nutrients solution where roots are suspended over the solution to extract the nutrient from it. Different type of technique is followed to grow plant using hydroponic which basically vary according to plant to plant, climatic condition and financial status [10]. DNN falls within the subtype of Convolutional neural network model inspired by a human brain implemented to control the environmental conditions where input parameters are temperature and water level. DNN needs a substantial extensive dataset as the quality of outcomes is intricately linked upon the datasets scale and the model acquires knowledge on this data. Several technology and industrial innovation involve robotics and machine learning, image processing, IoT model, computer vision and deep learning provide significant applications within the agriculture sector benefiting to both commercial farmers as well as traditional farmer [1]. Advanced and effective image processing will enhance the utility of drone-based AI technology making an asset [16]. It has comparatively more hidden layers that's why it has better accuracy than ANN. DNN are employed to achieve the accurate control over the modern and advanced hydroponic systems. The collected data is stored in cloud software [15]. The system can be designed as-

- Arduino component sensors designed for measuring humidity, pH, light intensity sense and capture data and send to microcontroller [15].
- Raspberry Pi3 housing a deep neural network model which has been trained using the dataset collected from the cloud is utilised. Pi3 will make appropriate decision and give an output decision [15].
- The output will be further sent to Arduino which activates the controlling system like-of pumping water, switching fans and lights [15].
- The data received by Pi3 will be stored in cloud for viewing and predicting [15].

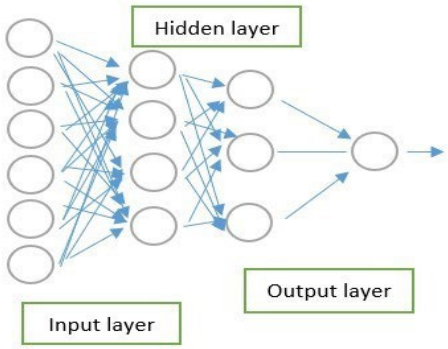

Fig 1: Deep Neural Network

For example, one of the important tasks in farming where DNN is applied is yield prediction. It aims to predict the expected crop yield for a particular region based on various factors. The crop yield prediction equation using DNN could be: -

Yield = f(N_{out} * σ(N_h * σ(N_{h-1} * σ(N₁ * X + b₁) + b₂) + ... + b_n)

Yield: Predicted crop yield, typically a numeric value.
f: Activation function of output layer, can be linear for regression tasks.
σ: Activation function used in each hidden layer of the DNN.
W_h: Weight matrix.
W_{h-1}: Weight matrix for the secondary hidden layer (if applicable).
W₁: Weight matrix for the input layer.
X: The input features, represented as a vector.
b₁, b₂, b_n: Bias terms for each layer in the DNN.

W_{out}: Weight matrix for the final output layer.[11-14]

4. Hydroponics

There are different viewpoints to observe evolution of hydroponics to understand its overall potential. It is related to Nutrition in plants. Humans are using this technique from thousands of years [26]. The study of Hydroponic elaborate the importance of mineral nutrients to grow plants [3]. This field is invaluable tool for both crop production as well as basic research. The paper studies a smart controlling and monitoring hydroponic system [19]. Hydroponics when collaborated with AI technology may result in predicting and sensing the data which is given by sensors, related to plants health and disease [20]. However, the system when collaborated with artificial intelligence neural networks may suffer from high complex computations. These systems are required to mention their levels in a manual mode through the application or software for the better understanding by farmer to runs on automated mode [20]. In hydroponics, the crop yield and harvest quality are typically higher than conventional farming because of better roots exposure to nutrient solution [9]. Resulting, farmers are shifting from traditional farming to modern way of farming.Different type of techniques which are used in hydroponic to grow plant which are as follow.

A- CIRCULATING METHODS-this method basically required a closed working system which should have proper continuous flow of nutrient solution culture [2].
1) -Deep water culture (DWC); within this framework plants roots are submerged in water and nutrient rich mixture inside a chamber where frequent air is supplied to the plant's roots [4].
2) Nutrient film technique (NFT);is work on phenomenon where a thin film of nutrients solution is flowing over the roots of crops through channel [10].
B- NON-CIRCULATING METHOD-this method also known as static systems which work on the principle of capillary action to transport the nutrient rich water to the plants roots [3].
1 Root dipping technique [3].
2 Floating technique [3].
3 Capillary action technique [3].
Crop which are grown in hydroponic are Cereals, vegetable, condiments, flower, medicinal crop, fodder crops [4]. Component of hydroponics system include temperature which range for winter season crop is around 10-13°C at night and 15-18°C day. For warm weather night temperature is 18°C and 24°C at daytime [5]. Electrical conductivity (EC) vary from crop to crop but an average is 1.0 to 2.0 Ms/cm [7]. Water level variable include low(400ml), normal(1000ml), high(2000ml) [13]. Most of the crop require almost relative humidity 75%, light intensity 5600 lumen for 14 to 16 hours each day [5]. Different growing media is required for different techniques which are used in hydroponics for different crops like coir, perlite, rock wool, sand, gravel, expanded clay, brick shards [6].[15-20]

5. IoT and hydroponics

Integration Internet of things (IoT) into hydroponics include involvement of sensors and controllers to monitor and regulate various aspects of hydroponics farming. Sensors are employed to gather the data which further send to IOT cloud for the provision of favourable environment condition for plants growth [8]. IoT hydroponics prototype include hardware component such as microcontroller, sensors, raspberry Pi3, UART communication (universal asynchronous receiver-transmitter) [15]. The introduction of AI-SHES with IOT involve 3 phases. Preliminary phase involves hardware that is endowed with real time.

Various sensors which are used in hydroponic system are pH, EC, light intensity, humidity, water level, timer sensor [8]. Second phase consists of Deep learning convolutional neural network (DLCNN) model is for identification and classification of nutrient deficiencies, pest and diseases detection in plants [20]. Third phase, farmer can easily monitor and collect sensor data using android-based mobile application of their hydroponic environment system [20]. There are various processes that a plant must go through. So, to implement and handle multiple processes systems can be built like Real-Time Operating Systems (RTOS) and open-source software such as freeware.

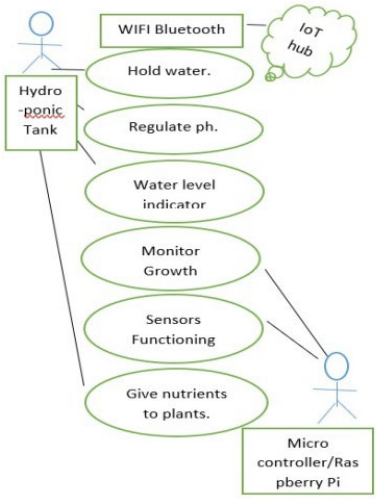

Fig 2: System components: Its responsibilities and contribution.

6. Result and discussion

This study aims to highlight the potential of new and updated version of modern technology used in developed countries in various agriculture related activities. Government should promote new schemes which provide financial support and training to the farmer to set up the modern technology on their traditional farming, so that farmer can easily adopt and get familiar with the technology. These areas should be with proper connectivity with cyber security measures. Adjust the sensor such a way that it easily detects automatically by using AI –camera to detect the signs of disease and pests' attack. When AI, IoT, and hydroponics come together, they create opportunities for trying out new ways to grow plants and for tailoring the conditions in which they grow. This can open the door to developing new types of plants or finding better methods for growing them [18]. It is very necessary to analyse the data with accuracy using cloud-based storage, Raspberry Pi and Artificial intelligence powered analytical tool [23].

Neural Networks can be used to create computer programs that learn from data collected over time. These programs can then predict how much crops will be harvested, when diseases might affect the plants, and how the plants will grow based on information from the past and what's happening right now [24]. This helps farmers and growers decide when to plant, how to use their resources, and when to harvest their crops more wisely.

Systems like Zig bee and Adriano with Bluetooth attached incorporated with WI Fi and communication models can be used for the early detection including disease, deficiencies, and diverse phenotypic traits of plants. DNN play a critical role in data fusion which create a comprehensive viewpoint of hydroponic system. CNN major role is to analyse visual representation of plants growth and development [22]. Cloud storage help in file

synchronization. The ability of DNN to process, analyse complex data, make early prediction, and finally optimize system parameter.

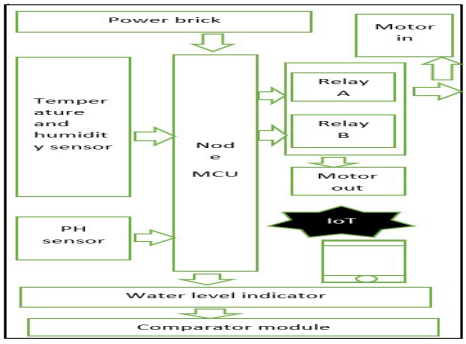

Fig 3: Smart hydroponic app: for IoT control and Alarm system

It helps automated nutrient, water, lighting, pest, and disease detection [22]. The Fuzzy logic which works on AI concept which is defined as a multivalued logic that allows for the illustration of intermediate values between binary evaluations [11]. The fuzzy logic works with reasoning and decision-making situation which is used in hydroponics.AI and IOT are playing a significant role in transforming industrial operations globally. Including wearable devices like smartwatches, augmented reality (AR)\virtual reality (VR) headsets, as well as advanced predictive maintenance sensors, integration of AL and IOT is unlocking an unprecedented capacity to process data more rapidly than before. Which enhance the overall productivity of the crops over a specific period.
Nonetheless there is optimism due to technologically driven with the advanced methods that empower farmers in addressing this challenge by increasing crop yield as compared to conventional methods.

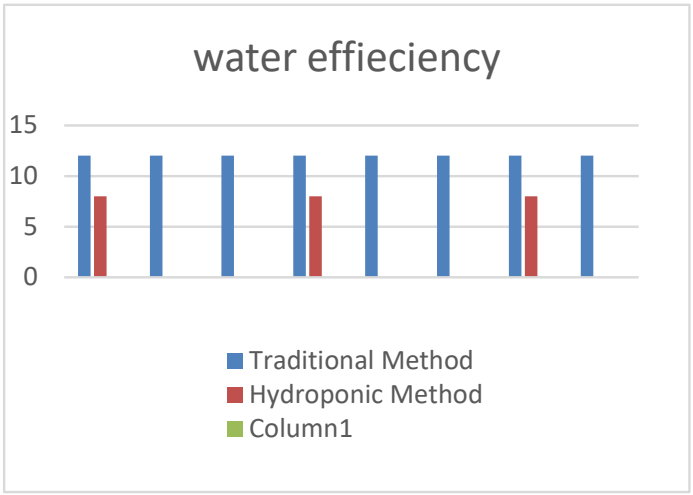

Fig 4: A Comparison of Water requirement: “traditional vs hydroponic farming

Hydroponic farming stands out remarkable efficiency in conserving water and nutrients solutions. The effectiveness of hydroponic was gauged by contrasting the data from its stock solution, as illustrated in figure 4 when compared to utilization of irrigated water in traditional agriculture. Within the hydroponic model, the average volume of water usage is only 2.48liters over 21 days, reflecting a substantial reduction of 97.42 percent contrasted

with the conventional system.Smart farming is a technologically advanced, high tech and capital-intensive system that aids farmers in an eco-friendly, clean, sustainable manner for cultivating the crops. The implementation of AI and IOT systems will empower farmers to optimize conventional farming processes and elevate their decision making on the farm.
1) Using data analysis to make informed choices in farming and agriculture [21].
2) Using automated farming equipment to enhance the quality of crops [7].
3) Reducing pesticide usage and promoting healthier soil [4].
4) Implementing predictive systems to establish flexible and efficient farming processes [12].
5) Minimizing uncertainty in sales and business operations [25]. [21-25]

7. Conclusion

The hydroponic farming with IOT and AI follow innovative and strongest approach towards precision and sustainable agriculture. DNN play a pivotal role in ensuring data accuracy and optimizing efficiency. With the help of sensors reduces manual monitoring. Due to urbanization and land scarcity adopting soil less culture which will improve yield and quality promote to food security in our country. The transformative platform like raspberry pi and Arduino together with diverse range of the sensors and actuators recently accessible in forum which will reshape micro and average scale precision farming system.[26 -28]

8. Future aspects

AI will play a crucial role in predicting the genetic potential of plants by analysing genomic sequence of plants, optimizing breeding strategies, speeding up crossbreeding, rapid prototyping, and data analysis. Iot and AI can boost the efficiency of supply chain optimization from production to distribution, help in market forecasting. Further it also assists aquaponics integration, indoor vertical farming, hydroponics livestock feed, ecosystem restoration, green roof and walls, cannabis cultivation, research and education. DNN will help in climate and environment monitoring, green house automation, agriculture robotics, soil health assessment, precision agriculture. The future of AI and IOT in agriculture holds great promise to increased efficiency and better decision making.[29-30]

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