Research Article

Pest Recognition and Cloud Monitoring in Aeroponic System

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Abstract | An advanced form of hydroponics, aeroponics farming is the procedure of plant cultivation in a mist environment by spraying micro droplets of nutrient solution on the roots of plant in a closed habitat in order to procure fast and healthy plant growth. It is a soil-less culture as soil is just the medium for the plant for nutrients ingestion. As nutrients are supplied in an air water culture in the form of mist directly to the roots. This type of farming uses the micro elements from the nutrient solution in the form of mist in a more efficient way than from soil. In this paper a goal of an automated aeroponics farming is advances in which focus is on eliminating present agricultural problems of Pakistan like water shortage, pest or insects, flood etc. The system is used to cultivate high quality crops while gathering continuous data and use this data to further improve the quality and production. Sensors are used for the continuous monitoring of temperature, humidity and light Intensity. These sensors data is updated every minute (up to user) to achieve real-time monitoring of the plant's environmental conditions. There is also an incorporation of Deep Learning algorithm named Convolutional Neural Network (CNN) for monitoring of pest. IP102 and different internet sources are used to gather the pest dataset. And also, the usage of IOT for remotely monitoring of the sensors data.

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Introduction

Aeroponics is a great solution for those with limited space or nations without enough land for irrigation when it comes to cultivating plants. In aeroponics, an oxygen- and nutrient-rich solution is sprayed on the roots of the plants using a sprinkler system. In an aeroponics system, the growing chamber is covered. This method of growing plants was initially developed in the 1920s by botanists who used it to study the root system. The plants are inserted into the holes in a net container, their roots hanging in the shadowy interior. The high pressure aeroponic pump is activated by a programmable cyclic timer, which also causes the nutrient solution from the nutrient reservoir to be sprayed as a fine mist in the rooting chamber. The spray particle's extremely small size significantly reduces the amount of nutrient solution that is wasted, and the supply of well-oxygenated solution fully prevents root rot. Simply put, an aeroponic system is a structure with the traits listed below. Growing room with holes for hanging plants and a dark compartment for roots below. Aeroponic high-low pressure misting system. Cyclic timer to sporadically turn the high pressure aeroponic pump on and off. Because various plants require varied environmental conditions for their optimum growth, such as the environment's temperature, the air's humidity, and the quantity of light they get each day, an automated environment is provided.

In addition to its impressive performance, the use of IoT allows users to remotely access pest identification data. The ResNet-50 model's depth, with approximately 23 million trainable parameters, enhances its capability for complex image recognition tasks. Achieving a 98% validation accuracy on a dataset of hand pictures, which includes 4,058 training photos and 122 test images, after only 10 training iterations underscores its efficiency and accuracy.

The paper is structured as follows. Section I provides an overview of aeroponics as a soilless cultivation technique, emphasizing its potential in addressing space and land limitations for plant growth. It introduces the integration of IoT (Internet of things) and deep learning for pest identification and highlights the objectives of the paper. In Section II present the review prior research related to aeroponics, IoT applications in agriculture, and the utilization of deep learning for pest classification. It serves as a foundation for the current study, drawing connections between existing knowledge and the proposed approach. In Section III we explore the aeroponic system's components and functionality, emphasizing its advantages over traditional soil-based farming. We delve into insect pest classification using CNN (Convolutional Neural Network) models, detailing the dataset, and explaining the IoT integration aspect with platforms like ThingSpeak for real-time data analysis. Section IV discuss the outcomes of our study. This includes an evaluation of CNN models like ResNet-50, VGGNet, and AlexNet for pest classification. We offer insights into accuracy and loss data for each model and make observations regarding spinach growth in aeroponics compared to conventional farming.

Finally, Section V interpret the results and their implications, focusing on the advantages of utilizing ResNet-50 for precise pest identification.

We engage in a discourse about the efficiency and benefits of aeroponic farming, emphasizing its potential in addressing food demand. Further section succinctly summarizes the primary findings and contributions of the paper, highlighting the promising prospects of aeroponics, IoT, and deep learning in agriculture.

Table 1: *Related work done for this paper.*

Introduction	Application	References
IOT-Based Automated Aeroponics System	An automated aeroponics system which uses sensors for measuring temperature, humidity, pH, light exposure etc.	(Francis *et al.*, 2018)
Modern plant cultivation technologies in agriculture under controlled environment: A review on aeroponics	Food sustainability; controlled environment; aeroponics; ultrasonic atomization; nutrient solution; plant production	(Lakhiar *et al.*, 2018)
AgriPest: A Large-Scale Domain-Specific Benchmark Dataset for Practical Agricultural Pest Detection in the Wild	Used their own dataset of agripest and implement certain neural networks.	(Wang *et al.*, 2021)
Insect pest image detection and recognition based on bio-inspired methods	Apply CNN (AN, DN, SN) on ip102	(Nanni *et al.*, 2020)
Feature Reuse Residual Networks for Insect Pest Recognition	Use ip102 dataset and apply FR-RNN, they modify the neural network also apply this on other datasets like cifar 10 and cifar100.	(Ren *et al.*, 2019)
Automatic Detection and Monitoring of Insect Pests. A Review	Make electronic trap for pests and insects.	(Cardim *et al.*, 2020)
Generative Adversarial Network Based Image Augmentation for Insect Pest Classification Enhancement.	Collected pest images from 5 greenhouse in 18 month and made a image classifier of 4 classes	(Lu, Chen-Yi *et al.*, 2019)
IP102: A Large-Scale Benchmark Dataset for Insect Pest Recognition	Used ip102 as the dataset and also distribute the dataset classes into crops field and then the network with resnet, alexnet and Yolo v3.	(Wu *et al.*, 2019)

Related work

This related work shown in Table 1 encompasses various aspects of agricultural technology and pest detection. The work discusses an IoT-based automated aeroponics system, focusing on environmental measurements. Further reviews modern plant cultivation technologies, with a spotlight on aeroponics and controlled environments. Moreover, the AgriPest dataset and its utilization for practical agricultural pest detection using neural networks. Also delve into insect pest detection, utilizing methods like CNNs, feature reuse networks, and even electronic traps for monitoring. Additionally, on generative adversarial networks for image augmentation in insect pest classification. Finally, researcher also discusses the IP102 dataset and evaluates networks like ResNet, AlexNet, and YOLO v3 for insect pest recognition in crop fields. These works collectively contribute to the advancement of agricultural and pest detection technologies.

Materials and Methods

One method of soilless growth is the aeroponic system, where plants are grown in air using artificial supports in place of soil as shown in Figure 1. In this method, the plant's lover cells (roots) are suspended in total darkness within a development chamber, and after a predetermined amount of time usually 50 to 60 seconds, a fine mist of nutrient solution is sprayed on the roots for 5 to 10 seconds. The portion of the plant above the growth chamber that is composed of the leaves, flowers, and fruits is expanding. The solution that contains all the essential elements necessary for plant growth provides all the nutrients that the plant needs. This approach enables improved oxygen absorption by the roots in addition to their absorption of vital minerals from the nutrient spray solution (Kasozi *et al.*, 2019). This significantly lowers the amount of water used (by 90%), speeds up development (by 40%) more than in soil, and dramatically reduces the amount of nutrients used.by (70%). The technique is economical in the use of fertilizers and saves water in compared to other conventional farming methods. Several studies practiced this technique and observed fast growing time along with high yield. The method is one of the most intensive farming processes, with an emphasis on high-value goods. Studies reported that plant nourish quickly in controlled environment. Controlled condition include temperature, humidity, light intensity (Francis *et al.*, 2018), spraying interval oxygen and CO_2. Controlling all parameter can result in higher efficiency which eventually result in higher yield thus more profit.

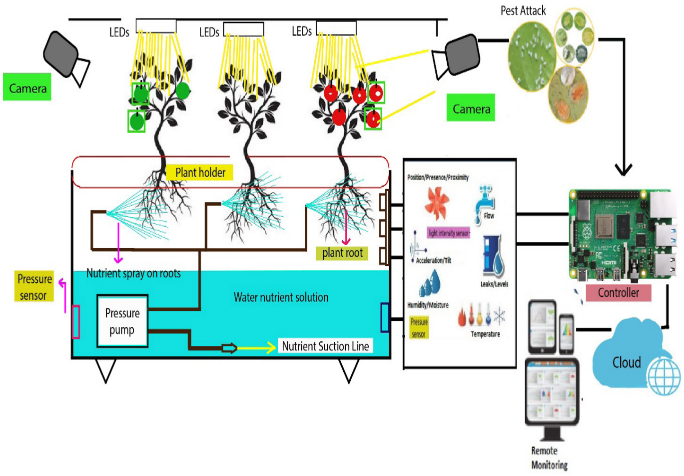

Figure 1: *Automated smart farming testbed.*

Main parts involved in the system

As show in (Figure 2) aeroponics system is composed of three major components, which are as follows:

(1) Mechanism for supplying nutrients

(2) Plant's growing part

(3) Growth chamber.

Figure 2: *Design and components of an aeroponic system for the propagation of spinach plants.*

The growth chamber is the same types of containers that are used to hold the plant roots in the air under complete darkness.

It contains a holding tray, misting mechanism and nutrient solution. Misting mechanism include atomizing nozzles which are connected to water pump through pipe. The growth chamber can be made from plastic, aluminum and plastic material, but wood has to be properly protected against water leakage. It is recommended to use dark colored opaque plastic because plants root need complete darkness for growth and this material doesn't allow light to pass through it.

Translucent plastic material is not recommended because it allow light to pass through it which encourage the growth of algae, but if the box is completely wrapped with aluminum foil or any wrapping tape and light cannot pass through it then this chamber can be used.

The atomizing nozzles are assembled in the chamber in such a way that the nutrient solution is sprayed directly onto the roots.

The material required for building aeroponic system were A1 = pneumatic t connector with 0.3mm steel nozzle (misting nozzle), A2 = 35cm*20cm*20cm plastic box (growth chamber), A3 = 70W diaphragm DC water pump, A4 = 32cm*18cm*14cm PVC pipe fitting (misting mechanism), A5 = 60cm*45cm*70cm wood chamber (enclosed environment), A6 plant holding cup, A7 12V axial fan, A8 12mm rubber pipe, A9 aluminum foil (for wrapping around growth chamber, A10 12V LED growing light (containing red, blue and white LEDs), A11 water filter, A12 mild steel tubes (for making stand for wood chamber. The cost of setting up a prototype of an aeroponic system in Pakistan can vary significantly depending on various factors, including the system's size, complexity, and the quality of materials and components used. However, we can provide you with a rough estimate of the basic costs involved in setting up a small-scale aeroponic system for experimentation or prototyping around 1 million rupees.

Aeroponics versus cocopeat

Effects of spinach growth in cocopeat vs. in aeroponics as shown in Figure 3 after the growth of 1 week spinach grows few cm in cocopeat and in aeroponic but after the growth of 4 week, there was a huge difference between the growths of both systems. In cocopeat plant grows 5 cm and in aeroponic system plant grew up to 7 cm.

Parameters used for aeroponic system

Potential of hydrogen (PH): Because it influences the nutrient availability for plant development, the proper pH level is crucial. A pH level that is excessively high can inhibit the intake of nutrients, cause deficiencies, and hasten the death of plants. Aeroponic systems that feed the roots with spray utilize a lot less liquid, making it simpler to control the fertilizer content and ensuring superior pH stability.

Figure 3: *Spinach growth in aeroponic.*

DHT 22: To getting the data accurately DHT 22 is best as it has the better measuring range of humidity from 0 to 100% with ±2% accuracy and for temperature it is -40°C to +125°C with ± 0.5% accuracy. Compared with DHT 11 provides range of 20 to 80% with ±5% accuracy for humidity and temperature range is from 0°C to 50°C with ±2°C accuracy.

Electric conductivity (EC): The total ions in the nutritional solution are what the EC takes into account. The EC concentration has an impact on plant growth stage nutrition absorption, productivity, and tuber quality.

Light intensity (BH1750): The ideal amount of light should have been given out by the plants. The maximum amount of photosynthesis occurs at this time, and plant growth is at its highest. If a plant receives less light, its growth will be slower. A light level of 4000 lux is exactly right for photosynthesis to occur at the same pace as plant respiration. At this degree of light compensation, plants can only survive and cannot develop. It may take a light intensity of up to 100,000 lux for the entire plant to become light saturated (Abeywardhana *et al*., 2021). On a sunny summer day, a greenhouse's light output may reach 130,000 lux; on cloudy winter days, it maybe it ranges from 1-65535 lux with ±20% accuracy.

Table 2: *Parameters used in this system.*

S. No	Parameters	Values	Instruments
1	Desired pH values of nutrient solution	The pH value generally depends on crop that is being grown. For spinach 5.5 to 6.5	PH meter
2	Humidity	70% to 95% moisture	DHT 22
3	Temperature	50 to 60 F	DHT 22
4	Atomization of nutrient	Mist size flow of nutrients at high pressure from 100 to 200-micron, low pressure from 10 to 50 micron	Nozzle atomization for high and for low pressure
5	Light intensity	12 to 14 hours of light per day	Light intensity sensor

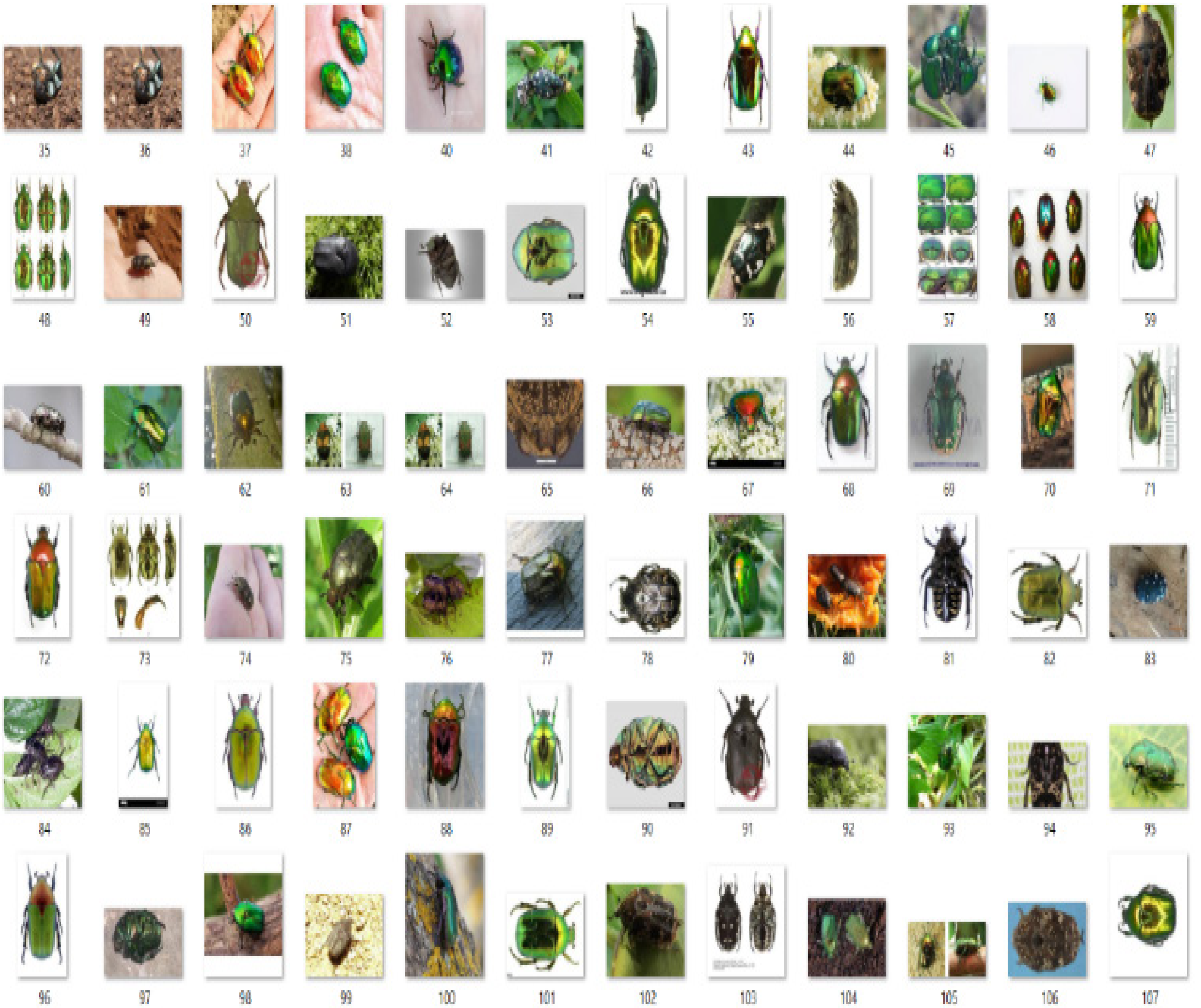

Figure 4: *Collection of insect images prior to image classification process (open data base).*

The level of nutrients in a system, or the salts of the system, are measured by EC. EC varies depending on the type of plant (Table 2).

The PH of a solution is a significant parameter that represents its chemical makeup. For plants to be healthy, PH should remain within (Table 3).

Table 3: *Data collected of different plants.*

Plant	PH	EC
Spinach	5.5-6.5	1.8-2.2
Tomato	4.8-6.0	2.5-5.0
Cucumber	5.7-6.0	1.7-2.2
Lettuce	5.5-6.5	0.8-1.2

Insects pest classification

Convolutional Neural Networks (CNNs) are a subset of multi-layer neural networks that were created with the goal of recognizing visual patterns directly from pixel pictures with the least amount of pre-processing. In order to improve categorization, CNN starts with the raw pixel data from the picture, trains the model, and then automatically extracts the features. Neural network using convolutions. An input layer, an output layer, and one or more hidden layers make up convolutional networks.

Five of the most prevalent insect pests are chosen for categorization from the insect pest Dataset IP102 (v7labs.com): aphids, armyworms, corn borer, grain aphids, and rice leaf rollers, as illustrated in Figures 4 and 5. To categories the photos into the five classifications, a deep CNN is constructed. Compared to conventional classification methods, deep learning models require substantially less pre-processing.

The CNNs used in this paper are: AlexNet, ResNet50 and VGGNet.
Based on strategy these models were evaluated on 2 stages.

- CNN models without using pre-trained weights.
- CNN models fine-tuned with transfer learning approach (using pre-trained weights).

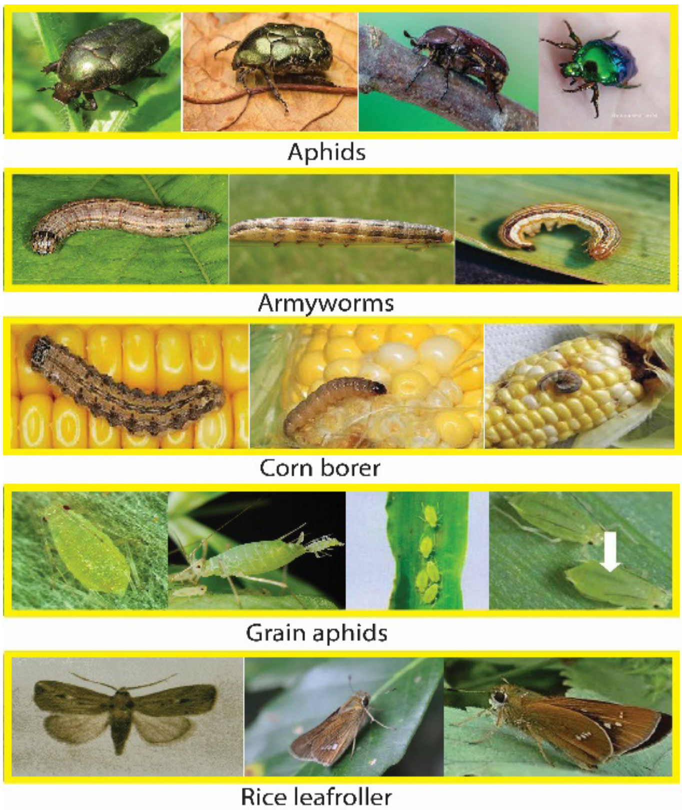

Figure 5: *Insects used in dataset (open data set).*

CNN models without using pre-trained weights

AlexNet: The conventional neural network design of stacked and linked layers is followed by this well-known CNN model. It has eight layers and is a CNN. The trained network is able to categories photos into 1000 different item categories. With the exception of the output layer, each of the model's five layers which combine max pooling with three fully linked layers uses ReLU activation (Rahman *et al*., 2018; Kasozi *et al*., 2019).

CNN models fine-tuned with transfer learning approach

Transfer learning is becoming a common practice (meaning that the classifier is already trained on a large-scale dataset like ImageNet dataset before the actual training begins). As a result, the classifier can only be tailored to the particular classification issue by training a limited number of high-level network layers in proportion to the quantity of training data available for the problem (Data set).

- VGGNet
- ResNet50

A CNN with 50 layers is called ResNet-50. More over a million photos from the ImageNet collection served as the training material for the network's pre-trained version. The trained network is able to categories photos into 1000 different item categories.

The CNN model contains three convolutional blocks for feature extraction with ReLU. ReLU is used as the activation function since it requires less computation time and has the highest probability for model convergence. Each convolutional block has two convolutional layers, two max-pooling layers, and one convolutional layer. Drop out and batch normalization are implemented to mitigate the problem of overfitting. Finally, two fully connected layers followed by a Soft max layer that is used to predict the class probability of the images. The objective of this research is to improve the performance of this CNN classifier with data augmentation based on generative adversarial networks.

Dataset

Insects are one of the major problems in agriculture. This problem should be prevented to avoid economic losses. For spinach the insects classified for detection purposes are shown in Figure 6.

As shown in (Figure 5) the collection includes 5 kinds of insect pests and 4059 photos. Sub-class divisions are used to separate the training and test sets. The dataset is divided into 102 testing pictures and 4059 train images. In-depth breakdowns at various levels are displayed in (Figure 6).

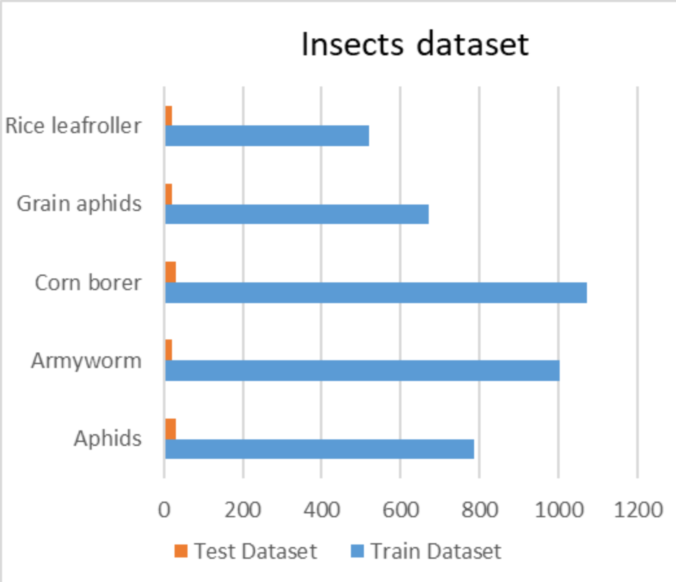

Figure 6: *Dataset of different insects.*

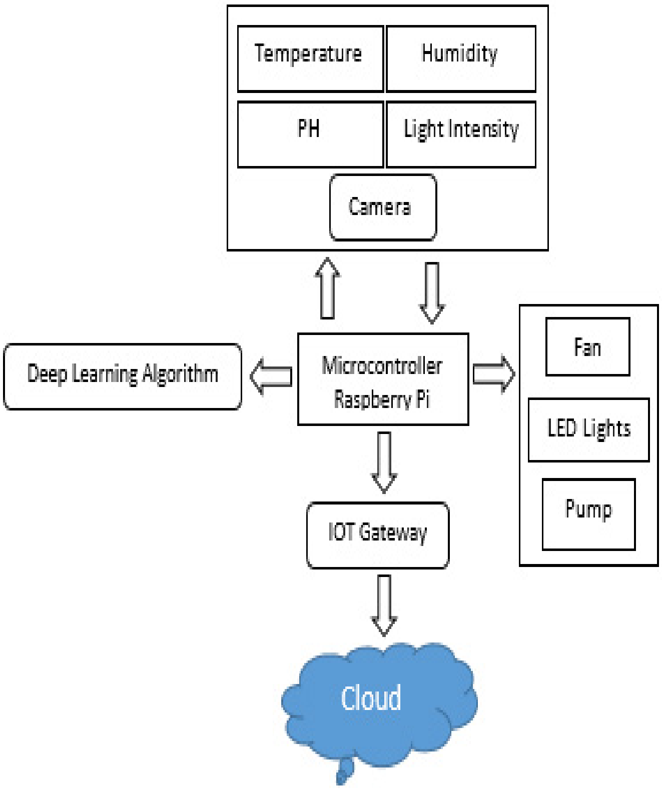

Figure 7: *Flow control of aeroponic system.*

Cloud based IOT platform in aeroponics

In an automated environment it's a bit hard to maintain the parameters like humidity, light intensity and temperature (Francis *et al.*, 2018). If these parameters are achieved by real-time monitoring it can result in high yield with low cost which keeps the greenhouse competitive for the conventional farming. IOT is being incorporated with the whole system as shown in (Figure 7) for uploading data of temperature and humidity. These data can be useful for others who are performing similar cultivations. The farmer can monitor the temperature and humidity through internet, as shown in Figure 7.

Figure 8: *Thing speak cloud interface for the proposed system.*

Thing speak is an IoT analytics platform service that allows to aggregate, visualize and analyze live data streams in the cloud. Thing speak provides instant visualizations of data posted by the system as shown in Figure 8. The integration of deep learning and the Internet of Things (IoT) in the context of aeroponics offers multifaceted benefits. Deep learning, particularly through CNNs, plays a pivotal role in precise and automated plant issue detection and pest identification. This capability significantly enhances crop health and reduces the reliance on broad-spectrum treatments, promoting sustainable and eco-friendly cultivation practices. Simultaneously, IoT-based sensors and systems facilitate real-time data collection and remote monitoring of crucial environmental variables, such as temperature, humidity, and nutrient levels, within aeroponic setups. This real-time insight allows growers to make data-driven decisions and adjustments to optimize growth conditions. Moreover, IoT-enabled remote control mechanisms empower growers to fine-tune these conditions even when physically distant from the cultivation site, ensuring consistency and efficiency in plant care. Additionally, the marriage of deep learning and IoT contributes to resource efficiency. By leveraging data-driven insights, growers can tailor resource allocation, minimizing water and nutrient wastage while maximizing plant growth. This resource-efficient approach not only reduces operational costs but also aligns with sustainable agriculture practices by conserving valuable resources. Furthermore, the adaptability of these technologies makes them suitable for a wide range of agricultural settings, from small urban spaces to large-scale commercial operations. Whether optimizing a small indoor garden or managing extensive crop fields, the integration of deep learning and IoT enhances productivity, crop quality, and overall agricultural sustainability. In summary, this collaborative approach represents a transformative leap toward data-driven, efficient, and environmentally conscious aeroponic cultivation.

To ensure uninterrupted aeroponic operations: Backup critical data and store it securely. Have redundant equipment for key components. Use power backups (UPS or generators). Maintain a backup supply of nutrients and chemicals. Establish emergency protocols and remote monitoring. Conduct regular maintenance and maintain supplier relationships

Results and Discussion

In CNN networks Resnet 50 gives higher accuracy on the dataset utilized in the paper as compared to VGG19 and Alex Net. The accuracy of the ResNet-50 is 99% in 10 epochs that of the VGG-19 is 50% in 10 epochs, while Alex Net, on the other hand, and provides an accuracy of 80% as shown in Figure 9. However, as we can see from Mobile Net's training results, its accuracy is improving, and it is implied that the accuracy can undoubtedly be increased if the training is done for a higher number of epochs. However, we have demonstrated the implementation strategy and architecture for both models. ResNet-50 has a greater number of layers to be used so it can show better performance as compared to the Mobile Net. And for spinach it took 40 to 60 days for the completion of spinach leaves.

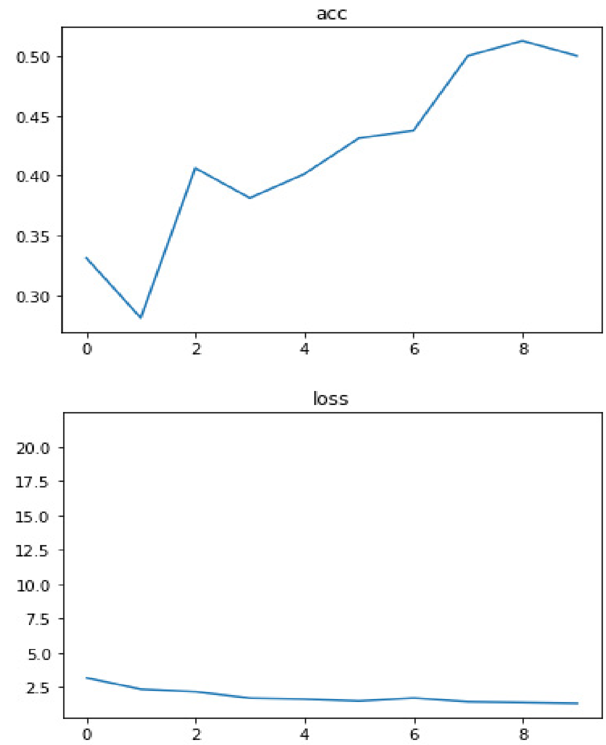

Figure 9: *Accuracy and loss of VGG-19.*

Accuracy and loss of Resnet-50. Accuracy is getting better as system is trained on 10 epocs and likewise loss is getting down as system is providing better results. In CNN networks Resnet50 gives higher accuracy on the dataset utilized in the paper as compared to VGG19 and Alex Net. The accuracy of the ResNet-50 is 99% in 10 epochs that of the VGG-19 is 50% in 10 epochs, while Alex Net, on the other hand, and provides an accuracy of 80% as summarizes in Table 4. However, as we can see from MobileNet's training performance, accuracy is improving, and it can be assumed that if the network operates for a higher number of epochs, accuracy will undoubtedly increase. ResNet-50 has more parameters available for use, hence it stands to reason that it will perform better than the other two networks.

Table 4: *Model complexity with validation accuracies of different convolutional neural network models.*

Deep learning model	Layers	Number of trainable parameters.	Accuracy
Resnet-50	50	4059	99.15%
VGG-19	19	4059	50%
Sequential API	3	4059	80%

In this network accuracy is improving but not going up more than 50% and loss is also is much higher as compared to the resnet system.

It took 3 days for spinach to germinate and 35 to 40 days in aeroponic system for complete spinach full of mineral like vitamin E and magnesium. Spinach grows faster than the conventional farming, normally it took 45–60 days for spinach completion fruit.

Accuracy and loss of AlexNet. In this network accuracy is constant but not going up more than 80% and loss is also decreasing but not giving the desired result as compared to the resnet system.

As the demand of clean, fresh and nutritious food is increasing day by day with the daily growth in population. Most of the people will adopt new plant growing technique to full fill increasing food demands. Moreover, this paper concluded that aeroponics is the modern, innovative and informative technology for plant cultivation without usage of the soil. This is the best plant growing technology in many aspects compared with many other cultivation systems. The system is the fastest growing area of contemporary agriculture and is gaining speed and popularity swiftly. In nations with poor natural resources for producing vegetables, it would be used successfully.

Aeroponics, a soilless plant cultivation method, has commercial potential in several areas: Urban farming and controlled environment agriculture. Commercial crop production, focusing on high-value crops. Development and sale of aeroponic systems and equipment. Education and training for aeroponic system setup. Integration with smart farming technologies. Sustainability-focused marketing. Vertical integration of the supply chain. Partnerships with food-related businesses. Exporting aeroponic technology and expertise. Success in commercializing aeroponics depends on addressing system challenges and demonstrating economic viability and sustainability.

Conclusions and Recommendations

This paper delves into the innovative realm of aeroponics, a soilless plant cultivation technique that offers a promising solution for modern agriculture. Aeroponics involves suspending plant roots in an oxygen- and nutrient-rich mist, resulting in faster growth, reduced water and nutrient usage, and improved crop yields. The integration of IoT technology enhances the precision and efficiency of aeroponic systems by enabling real-time monitoring and remote control of crucial environmental variables. Furthermore, this paper explores the application of CNNs in the context of pest identification, demonstrating their capacity to classify common insect pests with remarkable accuracy. The ResNet-50 model emerges as a standout performer in this regard, achieving an impressive 99% accuracy in 10 training epochs.

The adoption of aeroponics holds significant potential for addressing the increasing demand for fresh and nutritious food in a world with a growing population. Its advantages, including rapid growth, resource efficiency, and adaptability, make it a compelling option for both urban farming and commercial crop production. While aeroponics shows promise, successful commercialization hinges on overcoming challenges, demonstrating economic viability, and ensuring sustainability. By addressing these hurdles and leveraging partnerships, smart farming technologies, and vertical integration, the aeroponics industry can contribute to sustainable agriculture and food security in the years to come.

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Novelty Statement

The novelty of the described research lies in the integration of advanced aeroponics farming techniques with cutting-edge technology, including automated systems, continuous data collection from environmental sensors, and the application of a Convolutional Neural Network for pest monitoring. This approach represents a significant advancement in addressing prevalent agricultural issues in Pakistan, such as water scarcity, pests, and flooding, while simultaneously enhancing crop quality and production. Additionally, the utilization of IoT for remote sensor monitoring adds an innovative dimension to the agricultural framework.

Author's Contribution

Ehtesham Khan: Wrote abstract, Methodology .
Talha Ahmed: Did SPSS analysis,Data entry in SPSS and analysis.
M. Irfan Anis: Conceived the idea,Overall Management of the article.
Syed Ahsan Rehman: Result and discussion, References

Conflict of interest
The authors have declared no conflict of interest.

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