



# "Smart Agriculture using IoT, Leaf Disease Detection using Machine Learning"

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**Abstract :** Hydroponics is the soil less agriculture farming, which consumes less water and other resources as compared to the traditional soil-based agriculture systems. However, monitoring of hydroponics farming is a challenging task due to the simultaneous supervising of numerous parameters, nutrition suggestion, and plant diagnosis system. But the recent technological developments are quite useful to solve these problems by adopting the artificial intelligence-based controlling algorithms in agriculture sector. Therefore, this article focuses on implementation of mobile application integrated artificial intelligence based smart hydroponics expert system, hereafter referred as AI-SHES with Internet of Things (IoT) environment. The proposed AI-SHES with IoT consists of three phases, where the first phase implements hardware environment equipped with real-time sensors such as NPK soil, sunlight, turbidity, pH, temperature, water level, and camera module which are controlled by Raspberry Pi processor. The second phase implements deep learning convolution neural network (DLCNN) model for best nutrient level prediction and plant disease detection and classification. In third phase, farmers can monitor the sensor data and plant leaf disease status using an Android-based mobile application, which is connected over IoT environment. In this manner, the farmer can continuously track the status of his field using the mobile app. In addition, the proposed AI-SHES also develops the automated mode, which makes the complete environment in automatic control manner and takes the necessary actions in hydroponics field to increase the productivity. The obtained simulation results on disease detection and classification using proposed AI-SHES with IoT disclose superior performance in terms of accuracy, measure with 99.29%, and 99.23%, respectively.

## I. INTRODUCTION

IoT in agriculture might be a game changer for humans and the whole planet. We are now seeing how harsh weather, eroding soil, drying areas, and collapsing ecosystems make food production more difficult and costly. Meanwhile, we are not getting any fewer. According to a well-known forecast, there would be more than 9 billion people in 2050. Fortunately, owing to quickly emerging technology and IoT applications for smart farming, there is still hope. According to analysts, this industry will reach 23.14 billion US dollars by 2022, with 75 million IoT devices implemented for agricultural applications in the following several years. The Internet of Objects is all about making "dumb" things "smart" by linking them to one another and to the Internet. It permits the remote sensing and control of physical things, allowing for more direct integration of the real world with computer-based systems. IoT allows devices equipped with sensors to communicate and interact with one another via the Internet. Pumps, barns, and tractors, as well as weather stations and computers, may all be remotely monitored and operated in real time. Agriculture is the only source for food production in many countries including Ethiopia, India. It is a wealthy industry, but over the years, people and work force involved in this industry are reducing drastically. The traditional farming face lots of challenges for increasing the productivity. Some of the challenges in rural areas are the global climate changes, pollutions, losing soil integrity to grow the crops, rapid increment in urbanization, and agricultural land sacrifice etc. Therefore, farmers need to employ smart farming as shown in Figure 1, which can help in increasing the food yield production. In addition, these new methods of farming along with traditional farming methods need some technological backing to counter global food crisis. To meet these challenges, it is necessary to adopt new technologies in farming like hydroponics, vertical farming, and polyhouse. Among those, the hydroponics is the best farming method, which directly involves with the technological requirements.

Some of the problems presented in the hydroponics are seedling (wilting, dead roots), system clogging, infestation (algae, pest), and nutrient deficiencies. Because seedlings are susceptible to issues when they are in the beginning stages of their development, one of the most difficult tasks in the process of producing plants in hydroponics is cultivating healthy seedlings. Wilting occurs when a plant loses its stiffness, and its leaves begin to dry up. Wilting may be caused by a number of circumstances, including insufficient watering or extreme temperature. There are a variety of factors that may contribute to dead roots, including the water's high temperature, a very high or extremely low EC, and over watering in thick substrates. Roots that have died might be an indication that a root rot pathogen is present in the system. It is generally agreed that clogging is the issue that arises most commonly in hydroponic systems, and this is particularly true for drip-style systems. The majority of the time, the tubes get clogged as a result of fragments of the growth media that become lodged inside of them. The circulation of the whole system is disrupted when there is clogging, which may cause significant harm to your crops. There is no way for producers to completely

eliminate the risk of infection in hydroponic farms, no matter how well they manage their operations. During the early stages of an infestation, there are a few actions that you may do to combat the problem. In most cases, a grower will be able to identify a specific nutrient deficit by evaluating the symptoms, but this method is not fool proof and may occasionally lead to incorrect conclusions. Checking the water temperature, pH of the nutrient solution, and electrical conductivity of the solution should come first before determining whether or not there is an issue.

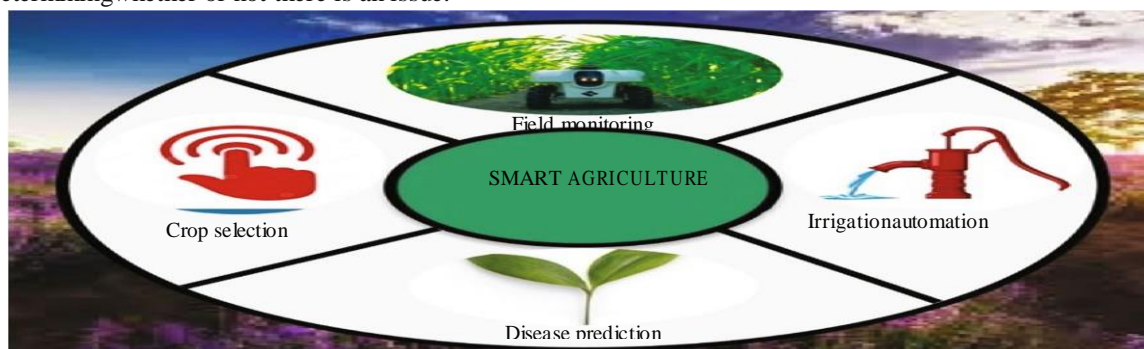


Figure 1: Sample illustration of smart farming

Recently, AI-based autonomous robots with a variety of hardware controllers and industrial robots are playing the key role in hydroponics for mentoring of plants. However, they are failed to monitor the multiple sensors at the same time to solve the above-mentioned problems. Another major challenge presented in the traditional farming and hydroponics is the plant diseases, which affect the growth of plants and thereby reduce the productivity. Traditionally, either farmers are manually classifying the diseases or pathologist are identifying the disease through lab experiments. However, the performance of traditional systems is purely depending on their experience, and it also a time-consuming task. Further, the early detection and prevention of plant diseases can improve the hydroponics performance. Therefore, recently, image processing-based computer aided methods are widely developed for benefit of the farmers. Thus, image processing technologies for early detection and diagnosis is preferred, which is done by using color feature extraction, texture extraction, and shape feature extraction. To overcome these problems, the major contributions of these works are illustrated as follows:

- a. Design and implementation of AI-SHES by intergrating Raspberry Pi controller, IoT environment with mobile application
- b. Implementation of user-friendly environment for farmers using AgriHydroponic application, which provides hybrid monitoring and controlling of hydroponics farm field
- c. Development of IoT based cloud environment for global monitoring of sensor data
- d. In addition, an AI framework is implemented for alerting, and predictive analytics of sensor data, and plant diseases.

## II. LITERATURE REVIEW

This section deals with the detailed analysis of existing methods with the drawbacks. In , the authors developed the Internet of Everything (IoE), which is considered a modern platform for advancement of IoT. This system considered the advanced soil sensors for monitoring the crop field. However, the proposed system conserves higher energy and decreases the efficiency, while calculating the heat index of the parameters to observe the surrounding for growth of crops. Further, efficient management of irrigation system (EFIS) is developed for automatic water controlling to avoid the water scarcity problems in Ethiopia, Kenya, and South Africa countries. This work jointly monitors the soil conditions with water levels. However, this system reduces the current intake of the parameters and reduces the data transmission range of the system. Further, a machine learning model known as support vector machine (SVM) is developed for plant disease classification along with the sensor data. In this model, a camera model equipped controller is designed with moisture, color, texture, humidity, and temperature of the leaf. However, this method suffers with the high computational complexity. In , authors focused on implementation of calculational intelligence technique for prediction and utilization of nitrogen in wheat crops. The calculation depends on the analysis of image of crops, which are captured the image in the real time field with different time samples and different lighting conditions. Further, artificial neural network with genetic algorithm (ANN-GA) is used to classify the plant diseases. However, this method suffers with the low classification accuracies. Further, MicConvNet classifier is developed for red palm weevil larvae detection in initial stage for protection of date trees. This detection system consists of based on a modified mixed depth wise convolution network. Anyhow, this method did not implement the IoT environment due to complexity issues. Further, hybrid convolutional neural network (HCNN) is trained with dual image database. The database consists of previously infected images, which is used for training the database for such diseases. Secondly, texture, color, and morphology features are extracted from image. However, this method consumed higher training time for feature training.

In , the authors integrated the deep learning with IoT for automatic disease identification from plants. The IoT is used for remote sensing of field parameters storage, with modified ResNET51 model which was used on the cloud for purpose of building smart disease detection. This method suffers with the low classification performance. In , the authors developed the mobile application, which displays the sensor values in efficient manner by administrating the field. Further, IoT is used to store the disease affected region with specific classes. Further, DeepLens variations are introduced for continuous monitoring of data with ubiquitous access and reliability, which is accessed by cloud data integrating with recursive CNN classification. The RCNN is used to identify the condition of leaves of fruit trees and vegetable plan. However, this method is not useful for diagnosis of hand

full of plants and trees diseases detection. In addition, AI and IoT enabled smart agriculture technologies' system is developed with decision tree classification. The data from the hardware is processed by AI, which contains valuable data for prediction of the all the parameters of crop. However, this method suffering with power related issues in real time environment. In , the authors implemented the AI-based agriculture system with IoT environment, and this method gives the feedback to farmer for ideal maintaining of the crop production. The AI system utilizes fuzzy logic for predicting types of crop type, soil integration and weather conditions. In , the authors implemented the hydroponic automation system for plant growth analysis from seed stage to yield stage. Further, ESP32 microcontroller is used for controlling of different sensors and actuators. Further, LOTUS mobile application was updated with humidity, irrigation, and temperature monitoring. However, this method is a high computational complexity. In , the authors implemented the hybrid system with multiple monitoring parameters such as nutrient level, pH, and temperature of the water. Further, K-Nearest Neighbor(KNN) based machine learning approach is used to automate these parameters according to reference water levels generated by nutrient film technique. However, this method has low reliability and efficiency as compared to deep learning models.

### III. PROPOSED METHODOLOGY

This section gives the detailed implementation analysis of AI-SHES, which is developed by integrating the Raspberry Pi, IoT environment with mobile application. Figure 2 shows the architecture of proposed AI-SHES. An AI-SHES is developed with the user-friendly environment for farmers using Raspberry Pi controller, IoT environment with Agri-Hydroponic application. The farmers monitor and control their hydroponics farm field using AgriHydroponic application with manual and automatic controlling modes of operation. The Raspberry Pi controller-based hardware system is placed in hydroponics farm field, which monitors the status of plants using different sensors. Further, all these sensors' data is uploaded into cloud based IoT environment. An artificial intelligence system is placed across the cloud served with DLCNN, which continuously monitors the sensor data and plant disease status and sends the necessary alerts to the farmers using Agri-Hydroponic application. Finally, the farmer controls his hydroponics farm field during manual mode, so nutrients are supplied to plants as per farmer mentioned levels. In addition, the nutrients are applied to plants with standard reference levels during automated mode of operation. *Hardware Environment.* The proposed AI-SHES implemented with the Raspberry Pi controller with the different types of sensors. Figure 3 shows the hardware environment of proposed AI-SHES. This environment uses different sensor for analysis of different parameters in the hydroponics farming methods. The proposed AI-SHES controls the parameters such as temperature, water level, water with nutrient considered fresh water, excessive sunlight, drain water, and cooler for temperature reduction.

Further, sensor values are continuously updated in IoT based cloud environment. Here, the grove sunlight sensor is used for analysis of sunlight, which generates the parameters of light in the sun rays such as IR rays, UV rays, and visible rays. These sensor parameters can be used to determine the amount of photosynthesis taking place inside the leaf of the plant. The SHT-20 sensor is used for parameters such as temperature and humidity of atmosphere. In hydroponics farming, it is important to measure the minerals present in water continuously, because the nutrients are supplied to the plant's trough the water only. Therefore, the hardware environment of hydroponic system requires the greater number of water sensors. The DS18B20 waterproof probe sensor is used to measure the water temperature. Further, SEN0161 water sensor also used for extracting the  $P_H$  levels such as acidic and basic nature of the water. Then, WQ730 turbidity sensor is used to extract the turbidity of water. Further, NPK sensor is used to measure the amount of nitrogen, phosphorus, and potassium levels present in water, which acts as an alternative to soil moisture sensor. In addition, hydrostatic pressure level sensor also used for measuring the different water levels. Additionally, camera modules capture the images of plants with the specified time scale.

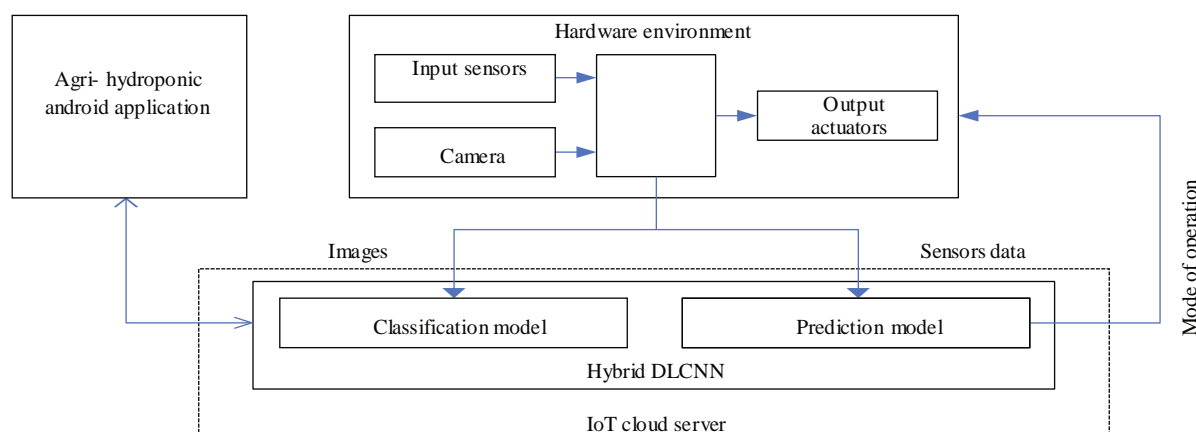


Figure 2: Proposed architecture of AI-SHES with IoT.

Finally, the Raspberry Pi receives all sensor values and images and sends these data to the DLCNN model of cloud server. Here, the Prediction-DLCNN model is effectively used to identify the nutrient deficiency of plants, which predicts the standard nutrient levels through comparison with trained reference levels.

In addition, the nutrients are applied to plants with standard reference levels during automated mode of operation. Further, the Raspberry Pi controllers control the output actuators (devices) based on the mode of operation generated by DLCNN environment. Therefore, the output devices such as motor and pump are controlled by this mode of operation directly from the mobile application. Here, two different pumps are used for pumping nutrient water and normal water, and they are supply water to plants till all the minerals and nutrients are observed. Further, heater output device is used to control water and air temperature

inside the hydroponics structure. In addition, motors are used to regulate the sunlight intensity by controlling the outer environment of farm field.

*AI-Based IoT Cloud Server.* The AI-SHES system contains two DLCNN models named as Prediction-DLCNN and Classification DLCNN, which are placed at the cloud server. Here, the Prediction-DLCNN model is used to estimate the perfect nutrient levels based on reference values. Further, the Classification DLCNN model is used to identify the different types of plant diseases. In addition, the operation of both models was performed in a parallel manner and updates the values to the farmer through mobile application. Figure 4 presents the architecture of Prediction-DLCNN. Here, input feature matrix is generated by concatenating the sensor data. Initially, the sensor data is monitored in the hydroponics filed during different environment conditions. Then, the RaspberryPi controller controls this data and transfers to IoT cloud. Then, the Prediction-DLCNN models take these sensor data as test input. The DLCNN model is trained with the reference nutrient dataset, where the dataset contains the perfect nutrient levels according to the different sensor conditions. The dataset is formed in different environmental conditions, so the Prediction-DLCNN model perfectly estimates the new nutrient values for every combination of sensor data in all atmospheric conditions.

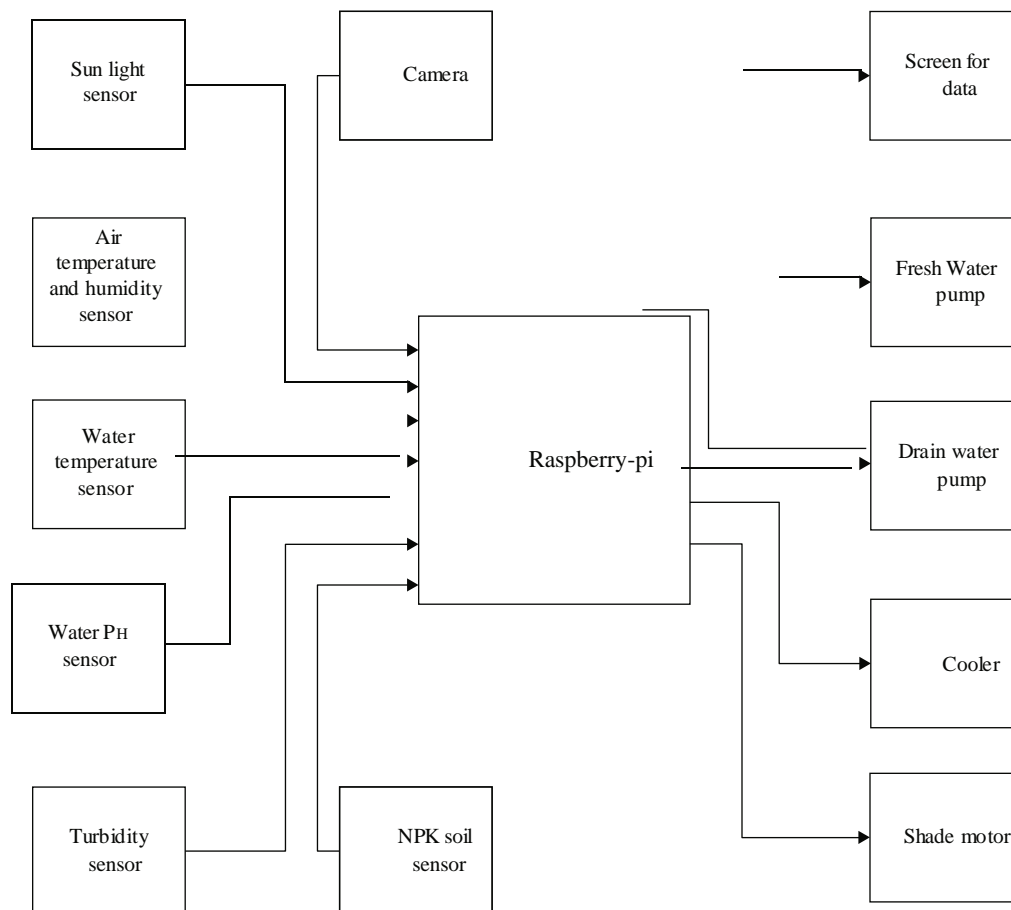


Figure 3: Hardware environment of AI-SHES system.

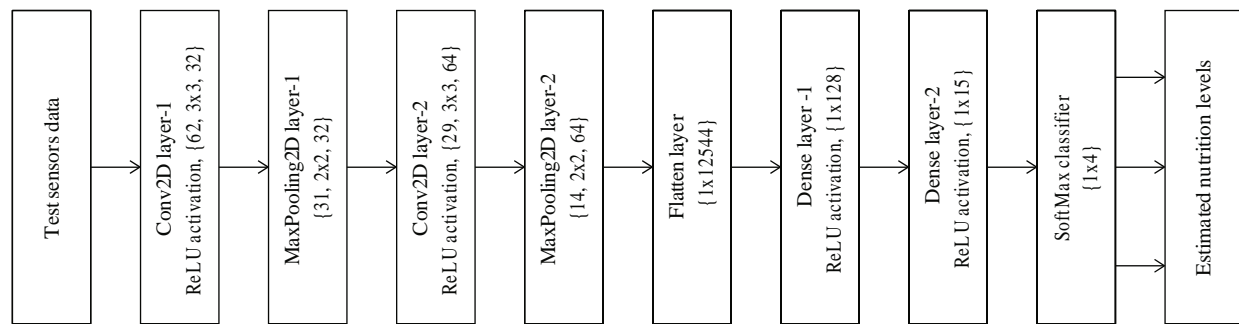


Figure 4: Architecture of Prediction-DLCNN model.

Figure 5 shows the architecture of Classification- DLCNN model, and Table 1 lists the description of layers employed in this architecture. The images captured in hydroponics filed are updated into IoT cloud through Rasp- berry Pi controller, and the same images are applied as input Classification-DLCNN model. The plants are suffering with different types of diseases due to nutrient deficiencies and disease attacks. Therefore, the proposed Classification- DLCNN model is capable of identifying the different types of diseases presented in plant images. Further, these disease classes and sensors' data monitored during test image cap- tured time are applied as input to the Prediction-DLCNN model. Now, the Prediction-DLCNN model estimates the new nutrient values based on input data. Finally, these infor- mation transfer to the farmer through Agri-Hydroponic application.

*Agri-Hydroponic Application.* The farmers monitor the sensor data and plant images continuously through the Agri-Hydroponic application. Further, the farmers can con- trol the different types of motors, actuators, and output devices placed in the hydroponic farm field using Agri- Hydroponic application as shown in Figure 6. In order to provide the security to the famers data, the application is Classification-DLCNN models.

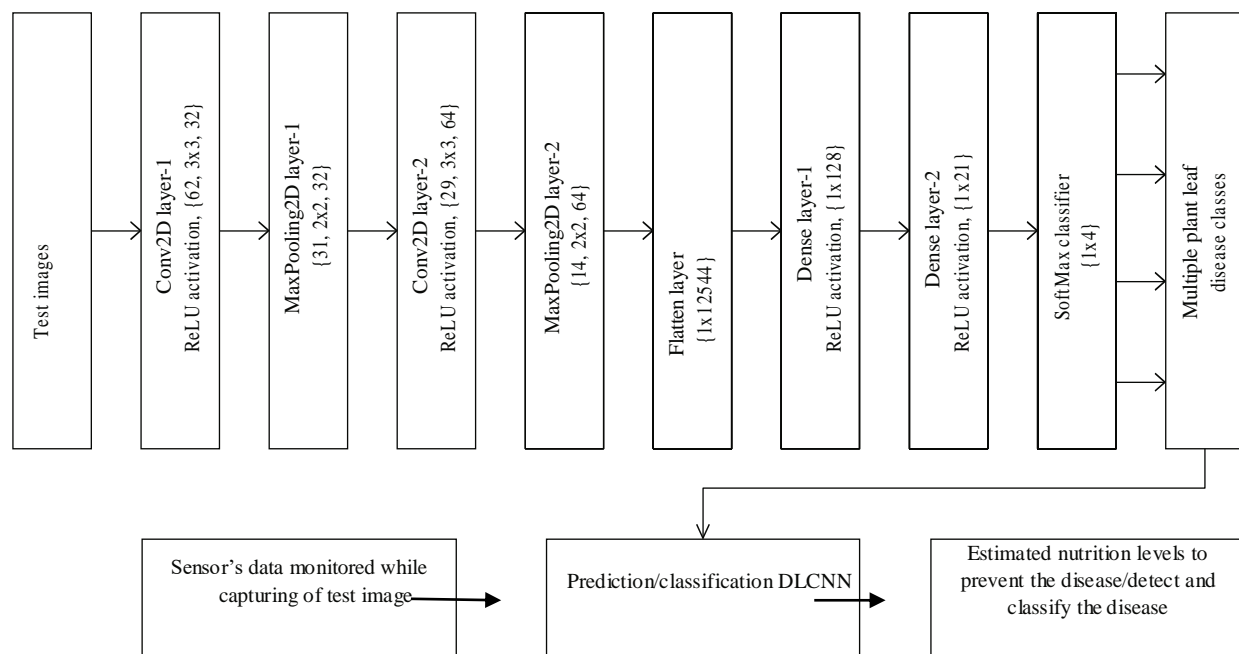


Figure 5: Proposed Classification-DLCNN model

| Layer name     | No. of filters | Filter size | Feature size |
|----------------|----------------|-------------|--------------|
| Conv2D-1       | 32             | 3x3         | 62x62        |
| MaxPooling2D-1 | 32             | 2x2         | 31x31        |
| Conv2D-2       | 64             | 3x3         | 29x29        |
| MaxPooling2D-2 | 64             | 2x2         | 14x14        |
| Flatten        | —              | —           | 1x12544      |
| Dense-1        | —              | —           | 1x128        |
| Dense-2        | —              | —           | 1x15         |
| SoftMax        | —              | —           | 1x4          |



developed with login page as shown in Figure 6(a). Therefore, intruders cannot control the field and cannot access the application. The RSA- and SHA-based hybrid security protocols are used in the application for maximum security. After successful login, the farmer can monitor and control the field using “plant disease prediction,” “farm sensor data,” and “farm controlling” buttons as shown in Figure 6(b). In the “farm sensor data” page, the different types of sensor data (water level, water turbidity, water pH UV light, visible light, IR light, air temperature, and water temperature, nitrogen, phosphorus, and potassium levels) are displayed as shown in Figure 6(c). The farmers can select the zone of hydroponics farm, which is divided into many sectors according to plantations. Therefore, the data is displayed based on average of all zones, whereas the farmer can also monitor individual zone-specific information. Further, the “farm controlling” operation is performed in two modes of operation such as automatic and manual modes as shown in Figure 6(d).

The farmers can control the devices presented in hydroponic field during manual mode through Raspberry Pi controller as shown in Figure 6(e). Here, UV light, visible light, and IR light-based sunlight parameters are improper; then, the motors control the poly-cloth placed at the hydroponic multiple layers. Further, air conditioner is manually controlled from the application based on air and water temperature levels. In addition, moisture inside the farm field also controlled based on humidity of the atmosphere. Moreover, the nutrient water supplied to plants also controlled by the drain water and freshwater motors based on nitrogen, phosphorus, and potassium mineral levels. All these input sensor data are monitored, and output devices are controlled automatically by Raspberry Pi controller during the automatic mode selection by the farmer in the application as shown in Figure 6(f). The farmers can also monitor the diseases presented in the plants during “plant disease classification page.” The Classification-DLNN model classifies the type of plant diseases and transfers to the “plant disease classification page” as shown in Figure 6(g). Here, the farmer can manually capture the images by his own, and Classification-DLNN model identifies the disease. Finally, the selected action (mode) of farmers is sent to the Raspberry Pi controller to control output devices through IoT cloud server.

#### IV. RESULTS AND DISCUSSION

This section gives the experimental and simulation results of proposed AI-SHES with IoT system. In addition, it also provides the performance of proposed Prediction-DLNN and Classification DLNN models compared to the state-of-the-art approaches using standard nutrition and plant leaf datasets.

*NUOnet (Nutrient Use and Outcome Network).* This dataset is collected by Agricultural Collaborative Research Outcomes System (AgCROS), which is a publicly available dataset. The most effective methods of nutrient management are very necessary for ensuring successful economic returns, preserving greater yields, minimizing negative effects on the environment, maximizing nutritional quality, and delivering electronic devices like mobile phones and tablets. It also shows the output devices like water motors controlling the supply of water in hydroponics field.

##### *Results of AI-Based IoT Cloud Server.*

Figure 8 shows the classified plant diseases using DLNN model. The proposed model accurately classified the apple scab, cherry powdery mildew, corn northern leaf blight, grape black rot, grape leaf blight, orange disease, peach bacterial spot, potato early blight, squash powdery mildew, strawberry leaf scorch, tomato early blight, and tomato late blight diseases.

Table 2 presents the Prediction-DLNN response for three samples of sensor data. Here, sample-1 data is considered during rainy season, sample-2 data is considered during winter season, and sample-3 data is considered during summer season. The Prediction-DLNN analyzed these sensor data and resulted in the perfect predicted nutrients. Further, Table 2 also presents the output action of actuators during automatic mode of operation.

Table 3 shows that the proposed Prediction-DLNN model accurately estimated the nutrient values as compared to state-of-the-art approaches like EFIS, SVM, Micro-ConvNet, and RCNN. These conventional methods considered the reference data during perfect atmospheric conditions, so they failed to result in the best prediction for all environmental situations. In addition, these conventional methods considered a smaller number of input sensors as compared to proposed system, which is also impacted the nutrition prediction performance.

Table 4 shows the disease detection and classification performance of proposed Classification DLNN. Here, the proposed method resulted in superior performance as compared to conventional methods like KNN, ANN-GA, HCNN, and ResNET51 for all performance metrics. This article presented the design and implementations of AI-SHES with IoT, which is developed by integrating the Raspberry Pi, IoT environment with mobile application. The farmer observes and manages his hydroponics farm field using the AgriHydroponic program, which has manual and automated control modes. A Raspberry Pi controller-based hardware design is installed in a hydroponics farm field to monitor plant status using various sensors. Furthermore, the data from these sensors is transferred to a cloud-based IoT system. An AI system is deployed in the cloud serviced by DLNN, which continually analyzes sensor data, plants disease condition, and gives alerts to farmers via the AgriHydroponic application. Finally, the farmer operates his hydroponics farm field in manual mode, ensuring that nutrients are provided to plants at the amounts specified by the farmer. Furthermore, nutrients are applied to plants at specified reference levels during automated mode of operation. This system can be extended with hybrid deep learning architectures and optimization methods.

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