A Novel IoT-Based Smart and Security System Model for Large Scale Farm Sustainability

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***Abstract*—The security and automation of work for large scale farm became major problem. Across the globe small scale farm have many techniques to implements but for large scale farm the technical data need to be analyzed for proper implementation of work. The main problem in farming is farming conditions now a days are unpredictable due to environment changes. Hence, we need to observe the environmental conditions for at least 3-years and save the data regarding rainfall and sunlight, O_2 and CO_2 levels etc. By analyzing such things, the framing can be improved. In this paper, a land near Amaravathi is considered and observed the conditions of soil moisture and prepared a data for further analysis of the study. Smart and Security (SAS) is the most important measure for all the farms to grow substantially. In this paper, the idea of involving Internet of Things (IoT), Global System for Mobile communication (GSM) Module, Global Positioning System (GPS) modules provide security and updated information of the specification to the farmer. Fingerprint based entry system into the farm helps to improve the security. The main objective is to help farmers in monitoring the entire farm land with the help of internet in hand and achieve important updates like soil moisture, temperature is sent to mobile via GSM module for every hour. The entire data collected from the sensors is updated in the cloud server. A dataset is created in the cloud server and will be further utilized for other farms. The articles present a smart and secure monitoring system for large agriculture farm by utilizing both hardware and software systems. A machine learning technique, i.e., deep convolutional neural network is utilized for the development and implementation of proposed model. The parameters like accuracy, sensitivity and specificity have been evaluated to know the performance of proposed model. The proposed model achieved an accuracy of 94.2% which is more efficient when compared to other existing techniques. The entire process has been simulated in MATLAB software tool.**

***Keywords*—Internet of Things (IoT), Global System for Mobile communication (GSM) module, Global Positioning System (GPS) module**

I. INTRODUCTION

Internet of Things (IoT) in agriculture has the potential to transform the game for humans and the entire planet [1]. We are now seeing how extreme weather, eroding soil, drier locations, and disintegrating ecosystems make food production more difficult and expensive. Meanwhile, there aren't any less. According to a well-known projection, there will be more than 9 billion people on the planet by 2050. Fortunately, there is still hope thanks to rapidly evolving technology and IoT applications [2] for smart farming. Recent days the emergence of IoT is been vastly influenced on agriculture. In recent years, agriculture has undergone a high range revolution and is termed as Agri-4.0 as Information and Communication Technology (ICT) has been successfully utilized into the process of conventional farming. Some of potential farming techniques include Machine Learning Techniques (MLT), Deep Learning Techniques (DLT), Remote Sensing Data (RSD), Analysis of Big Data (ABD), Internet of Things (IoT) and Unmanned Aerial Vehicles (UAVs) [3, 4].

IoT technology has the potential to be used in several sectors. Agriculture markets include, to mention a few, industry, transportation, healthcare, autos, and smart homes [5, 6]. One of the numerous elements influencing agricultural production is soil fertility. Soil fertility is an important aspect of agriculture that is controlled by a

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variety of factors, including environmental, human, and biotic factors, all of which affect nutrient levels and crop health sustainability [7]. The general sensors utilized for smart agricultural system is shown in Fig. 1.

Suma [8] provides a study of predictive estimations in designing cloud administrative Internet of Things (IoT), and security wholes for multi-breeding in the agricultural sector, all while taking farmers' prior experiences into consideration. The field data is collected using different sensors by Araby *et al.* [9]. Several crops like potatoes, tomatoes and so on are been cultivated and information is gathered. Sethy *et al.* [10] proposed a system that leverages deep knowledge and IoT to monitor paddy fields at random. For paddy leaf disease detection and nitrogen rank belief, the VGG16 pre-prepared network is being surveyed. Kaushik *et al.* [11] developed an intelligent agriculture system that monitors the agricultural field and can assist farmers greatly enhance output. Kaur *et al.* [12] suggested a strategy for effectively monitoring and governing bountiful crop progress and results. The cultivation in farm fields anticipated with use of Deep learning and IoT.

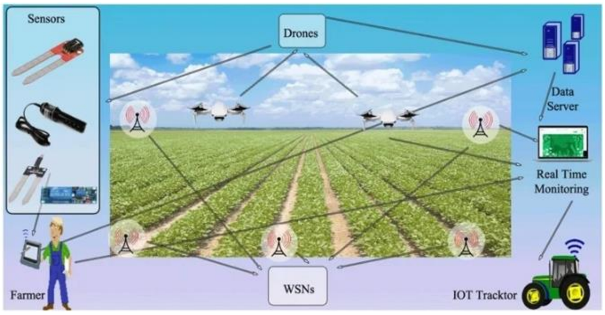

Fig. 1. IoT based smart agriculture monitoring system.

The problems of the twenty-first century have increased the demand for smart agriculture. Climate change, rising extreme weather events, population expansion, and soil degradation all have an impact on agricultural viability and the need to boost yields. If timely and consistent agricultural growth is to be ensured, solutions are required. Crop protection, yield forecasting, and land valuation are critical components of global food production and security.

For keeping agriculture in a sustainable possible the problems need to be identified. Identification of soil and management of the soil is one of the problems for the purpose of cultivation. Smart sensor and testing of soil conditions need be enhanced. Some of the problems are analyzing the temperature conditions, timely water management, lack of agriculture data for young generation who show interest in cultivation, etc. To overcome the above problems in this paper we designed a smart and secure agriculture system and data is gathered for analysis of agriculture data. The data gathered is also analyzed using deep neural networks.

The design structure of paper is as follows. In Section II, related work on IoT based agriculture system is discussed. Section III provides the management of soil and weather condition data. Section IV, the proposed Statistical Analysis System (SAS) model is discussed along the modules considered in the work and their interfacing with microcontroller. The analysis of entire agriculture data using deep Convolutional Neural Network (CNN) is discussed and results are evaluated.

II. Related Work

As the population of world has increased, so has the demand for reliable food supply and better farming techniques. Increasing demand for higher-quality, larger-quantity food has resulted in the industry's fast modernization, with breakthroughs in technology, infrastructure, and enhanced growing methods established in recent decades. The Internet of Things has a lot of potential uses in the modern agriculture sector.

The agriculture industry is under pressure. The world's population is expected to reach 10.1 billion people by 2050, increasing demand for land dedicated to food production. Food output need to be increase by 70% by 2050. In the field of smart farming, there has been a lot of recent study on the application of machine learning techniques. Agana and Homaifar [17] examined the issue of drought prediction using deep learning techniques. They presented an ensemble technique for predicting agricultural output over time. The accuracy and the classification error are the two measures used to anticipate the outcome. The IoT technology was used in [18] to regulate environmental problems in agriculture fields. It consists of three parts: a web application, a mobile application, and hardware components. Several IoT-based machine learning models have been reviewed in [19] about their unique designs and benefits to a variety of disciplines, including agriculture, the environment, and energy management employing IoT applications and methods based on machine learning. Mahbub [20] presented an intelligent monitoring system for agriculture that measures soil moisture and temperature. Without human interaction, the system processes the detected data and takes the necessary action based on the measurements of soil humidity and temperature.

Kishore *et al.* [21] described a method for utilising the collective model to anticipate water levels in combination with the level of severity of the disaster (flood). Khalaf *et al.* [22] offered a general overview of the different approaches to crop selection, crop seeding, threat detection, surveillance of systems, and ultimately production. The complete system that relies on processing images, the IoT's, machine learning, and AI was the focus of this effort. In order to collect data from these sensors and use ML techniques like Random Forest and GD-Boost, the system will include IoT sensors such as PH sensors, humidity, rainfall, temperature, and humidity [23]. By examining the correlation between many physical factors such soil temperature, soil moisture, air temperature, UV density, and air humidity with plant development, Khalaf *et al.* [24] advocated for the best use of water with greater yield. The detailed description of IoT in agriculture field, the hardware platform in IOT and role of sensors in IoT is discussed by Kour and Arora [15]. Górski [16] discussed an IoT-based network infrastructure for a sustainable greenhouse environment and deploy control mechanisms for efficient utilization of resources. The design of Unified Modeling Languages (UMLs) in IoT-Hardware is very useful for presenting diagrams in research publications, the study related to integral flow modelling of context architectures are presented by Agana and Homaifar [17].

With the sole objective of increasing farm output, smart farming is the application of intelligent data and communication technological advances systems, such as sensors, IoT, cloud-based processes, machine learning, artificial intelligence, networking, to the farming system, including crop cultivation, livestock farming, aquatic farming, and snail farming, to name a few. It may be extrapolated that smart farming entails the application of technology hardware as well as software solutions to enhance the performance of the farm.

Smart farming is a use of the IoT in agriculture, and computing is a key component of it. Farmers can store, handle, and analyze massive volumes of data collected from various IoT devices and sensors on their farms thanks to the cloud. The information gathered for the study may include statistics on weather patterns, soil moisture content, crop growth, and even livestock health. Farmers may boost production and efficiency by making better educated decisions regarding crop management and animal husbandry by analyzing this data in real-time. This article proposes and IoT system which helps in identifying the issues in farm and security access of the farms. For this purpose, the three stages are evolved, one is set up of sensors in the field, hardware setup for collecting of data and secure system, finally analysis of data using deep learning technique.

III. MATERIALS AND METHODS

A. Soil Management

Soil Monitoring with IoT enables farmers and producers to increase production, eliminate illness, and optimize resources by leveraging technology.

Data from IoT sensors is subsequently sent back to a centralized location (or the cloud) for analysis, visualization, and market assessment. Soil temperature is an important element in belowground plant activity, regulating things like root development, respiration, breakdown, and nitrogen mineralization. A probe embedded in the soil provides the most precise measurement. Multiple probes at varying depths can be inserted depending on the root structure of the plan in question. Surface soil temperature may be measured with an IoT sensor that use infrared new tech (Fig. 2).

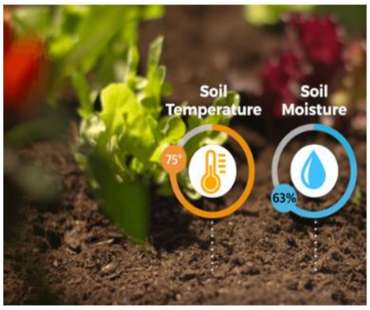

Fig. 2. Basic setup for soil management.

Light intensity is one of the important measures for the growth of crop. The light intensity also monitored continuously and based on it necessary precautions need to be taken. The Carbon dioxide (CO_2) levels and oxygen (O_2) level need to be noted with the help of sensors to identify the presence of available natural resources for the production of crop. The day and night monitoring level of all the four elements are considered and the data prediction is performed. The CO_2 level observed is shown in Fig. 3.

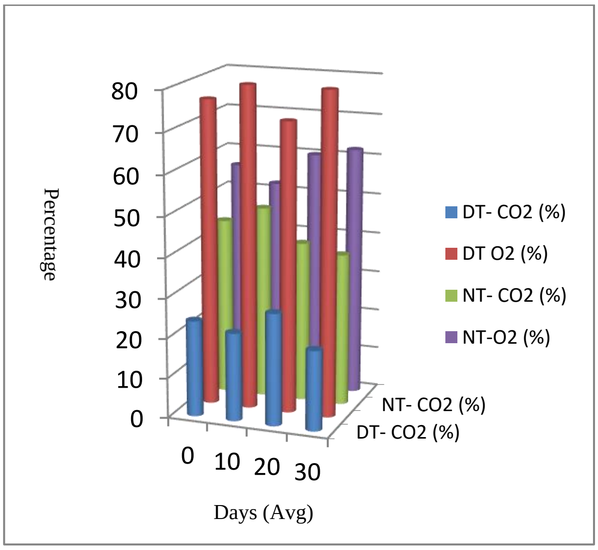

Fig. 3. Percentage CO_2 and O_2 during day time (DT) and Night Time (NT).

The inferences observed in the field to perform proposed work is shown in Fig. 3, in which the oxygen level in day time is observed to be nearly 82%, and during night time the oxygen level is around 68%. The CO_2 level observed during the day time is 22% and during night time CO_2 around 45%.

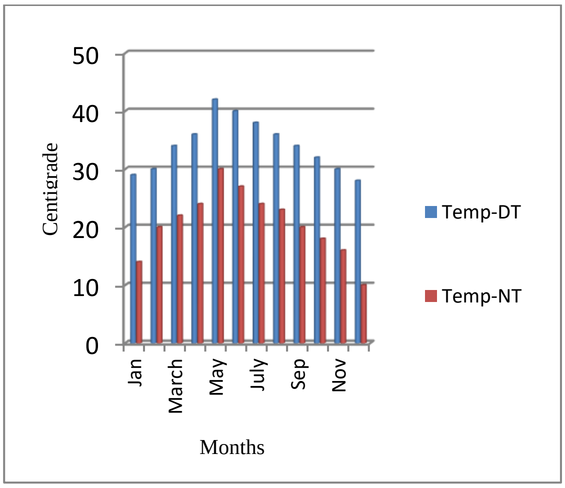

Fig. 4. Temperature noted near the farm.

The average temperature which is saved in cloud will be utilized to find the solutions for better crop management. The values of temperature estimated on average of every month are shown in Fig. 4. The estimations evaluated are based on the south India atmospheric conditions. The inferences observed in the field to perform proposed work is shown in Fig. 3, in which the oxygen level in day time is observed to be nearly 82%, and during night time the oxygen level is around 68%. The CO_2 level observed during the day time is 22% and during night time CO_2 around 45%.

The average temperature which is saved in cloud will be utilized to find the solutions for better crop management. The values of temperature estimated on average of every month are shown in Fig. 4. The estimations evaluated are based on the south India atmospheric conditions. In soil management we also need to identify the details of the soil which will help the farmer for doing suitable cultivation. Different type of soil form is shown in Fig. 5. The details of the soil for which the experimentation is performed given in Table I.

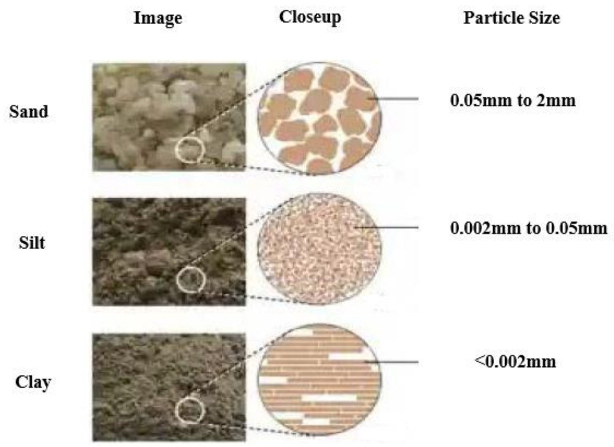

Fig. 5. Sand, silt, and clay.

TABLE I. DETAILS OF SOIL

Composition of Soil	Percentage Value (%)
Silt	35.2
Clay	5.4
Sand	57.4
Loam	2

B. *SAS Approach*

Smart and Security (SAS) farming solutions based on the Internet of Things (IoT) are a system that uses sensors to monitor agricultural fields and automate irrigation systems (Temp sensor, moisture sensor, CO_2, O_2, and so on). Farmers may monitor their farms from virtually any location using their mobile device. The Internet is one of the most cutting-edge wireless communication technologies available today. The process flow of work is shown in Fig. 6.

The soil which is used for performing the experimentation having a silt of 35.2%, clay 5.4%, sand 57.4% and loam of 2% and is shown in Table I. Based on the properties of sand the crop cultivation is performed. The database which is created is suitable for the fields with nearly above said percentages. The general framework of the SAS irrigation system is shown in Fig. 7, where the smart module consists of different sensors and the security module consists of Global System for Mobile communication (GSM) module, Fingerprint sensor module and Global Positioning System (GPS) tracking system.

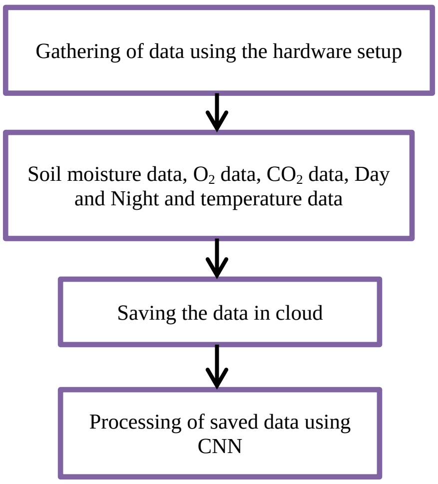

Fig. 6. Flow of proposed work.

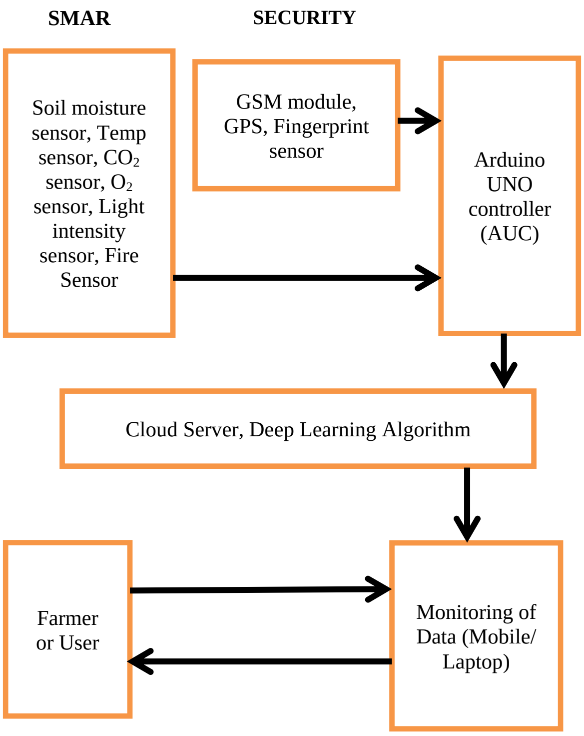

Fig. 7. Smart and secure irrigation system.

The algorithm steps of proposed SAS model is as follows:

Step 1. Initialize the power supply to all the sources via AUC.

Step 2. Checking for moisture level, low level moisture reported to Area under the Receiver Operating Characteristic Curve (AUC), i.e., less-than 30%, the motor come to on state and supply the water and motor turns off once the moisture reaches the required level.

Step 3. Checking of CO_2 and O_2 level and store the data in the cloud.

Step 4. Checking the temperature range and store the data in the cloud.

Step 5. Check for fire, if any smoke or fire detected water sprinkler is activated and SMS alert is sent to registered user/farmer.

Step 6. Register the finger prints of the persons who visit the farm for work, each registration alert is send to famer via SMS. Registration details to be entered are person name, age and identify number. The details are saved in cloud.

Step 7. If an unknown person tries to enter the farm with wrong fingerprint, detected alarm and SMS alert will be sent to farmer.

Step 8. Register the vehicles which are used to transport the cultivated product like mango, palm seed etc. GPS tracker is fitted to the vehicle.

Step 9. If the vehicle moves from destination, vehicle live location is monitored in mobile or laptop.

Step 10. Check for GPS, retrieve the coordinates from satellite, sent longitude and latitude via GSM and sending vehicle location to the user.

Step 11. Timely SMS alert will be sent to user regarding the status of the entire farm. The data is stored in cloud for further processing.

The interfacing of microcontroller with all the hardware components is performed in Fig. 7.

C. Evaluation of Methodology

The proposed hardware setup is shown in Fig. 8 and the model has gathered data for further analysis and prediction of resources for helping the famers in achieving good cultivation. The smart data is considered from IoT cloud server, i.e., CO_2 gas level, O_2 level, soil moisture, Intensity of light, temperature. These parameters are considered for performing the analysis of data using deep learning technique. The evaluation process is shown in Fig. 8, in which three important steps are been executed. The data collected from cloud is pre-processed. The day-to-day recordings of the farm land is stored in the cloud. The data which is stored consists of duplicate data, as the data overlaps. The duplicate data is removed in this preprocessing stage. The data is fed for Deep Convolutional Neural Networks (DCNN) for training and validating the model. The process of performing the proposed model is represented in Fig. 8.

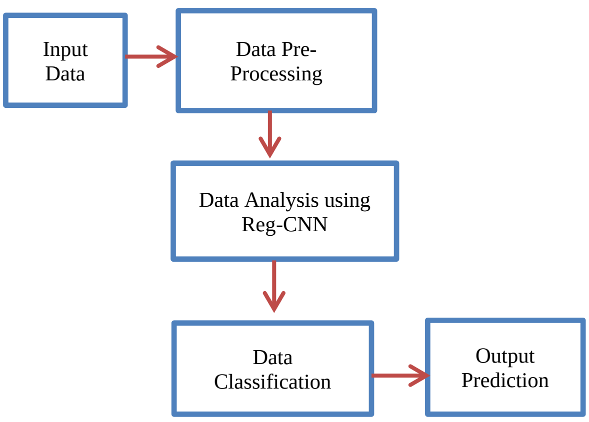

Fig. 8. Experimental evaluation of data.

D. Deep Convolutional Neural Network

This network is termed as a Multi-Layer Perceptron (MLP), and a basic network cannot handle large data for processing, to handle large amount of data deep learning techniques are considered.

The training and validation of data is performed using CNN model. The performance of CNN is observed in many applications like classification of images, identification of objects and recently used in most of the medical related analysis. The main function of CNN is to extract the valuable features from the higher layers of the network and transfer to lower layers for achieving best results. The layers that are connected in CNN are shown in Fig. 9.

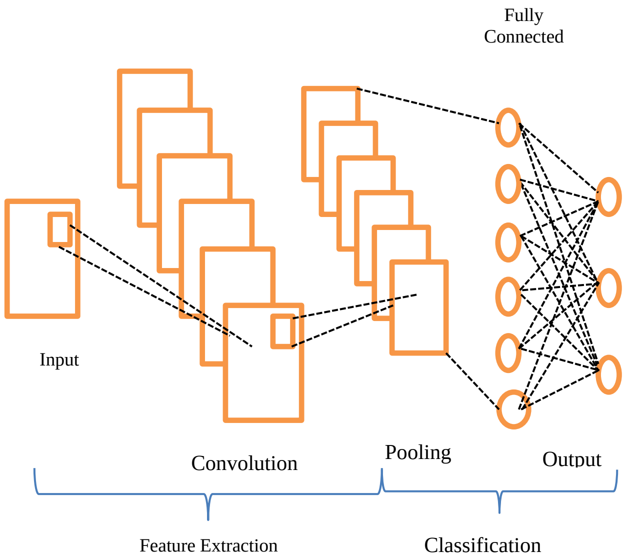

Fig. 9. Basic CNN architecture.

The complete structure of CNN is shown in Fig. 9 which consists of three important layers, they are: Convolutional layer, Pooling layer, and Full connected layer. The feature mapping in the first layer of CNN consists of kernels and these kernels are used for computing the tensor of features. The complete inputs of the network are been convolved with the help of strides, with the help of strides the kernels change the dimension of the output into integer form. As soon as the convolution process is completed, all the input volumes are been shrink. The size of the input volume needs to be maintained with low level traits when padding input with zeros and the process is called as zero padding. This is one of the necessary aspects in CNN to boost the performance. The convolutional layer's operation is as follows:

$$F(i,j) = (I * K)(i,j) = \sum\sum I(i+m, j+n)K(m,n) \quad (1)$$

where the input matric is termed as "*I*", the "*K*" in above equation denotes a 2D filter of size m × n, and "*F*" is the representation of output of a 2D feature map. The convolution operation is denoted by "*" and is performed between *I* and *K* (*I***K*). The Rectified Linear Unit (ReLU) which is used to increase nonlinearity in feature maps. The

ReLU activation is computed by keeping the threshold input at zero. It is mathematically expressed as follows:

$$f(x) = \max(0, x) \quad (2)$$

To limit the number of parameters, the pooling layer down-samples a given input dimension. The most frequent approach is max pooling, which creates the largest value in an input area. A regression layer is included to improve the performance of data validation. The proposed Reg-CNN model is shown in Fig. 10.

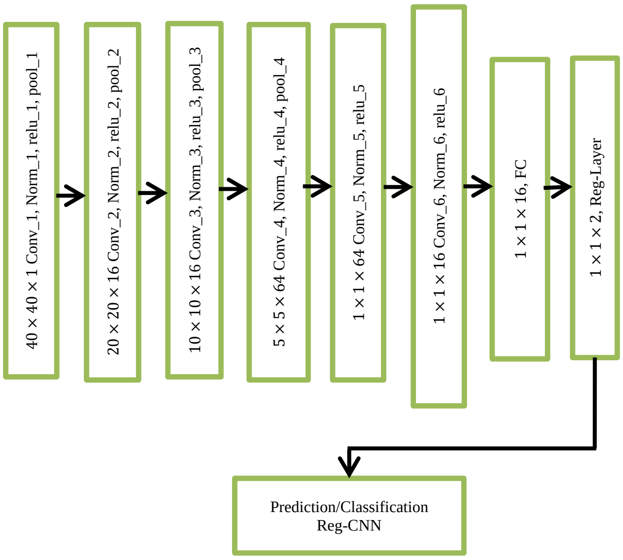

Fig. 10. Training and classification DCNN model.

Finally, the data is classified for achieving the required output. The Fully Connected layer serves as a classifier, making a judgment based on characteristics acquired from the layers of convolutional and pooling.

IV. Analysis of Simulation Results

The suggested experimental strategy is based on a prototype that has been field-tested on crops under varied situations. The obtained dataset contains CO_2 gas level, O_2 level, and moisture of soil, intensity of light, temperature feature attributes. The dataset values are collected over a period of many months and eight hours each day. The average of every day's readings for each sensor characteristic is saved in the cloud. The analysis of the data is performed used MATLAB tool and programed a model that helps in decision making. The machine learning toolbox which are available in MATLAB is been utilized to evaluate the suggested methodology.

A. Parameters Evaluated

1) Sensitivity

Sensitivity (also known as the true positive rate, recall, or probability of detection in some disciplines) is a measurement of the proportion of true positives that are accurately identified.

$$\text{Sensitivity} = \frac{TP}{TP+FN} \quad (3)$$

2) Specificity

Specificity (also known as the true negative rate) is the percentage of genuine negatives that are accurately identified.

$$\text{Specificity} = \frac{TN}{TN+FP} \quad (4)$$

3) Accuracy

Accuracy is defined as a mixture of the two forms of observational error discussed above (random and systematic), thus good accuracy necessitates both precision and trueness.

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \quad (5)$$

The parameters evaluated using the proposed model is shown in Table II. The proposed model is compared with existing models.

TABLE II. Comparison of Evaluated Parameters

Reference	Accuracy (%)	Sensitivity (%)	Specificity (%)
Rezk *et al.* [13]	87.35	87.33	95.7
Rokade *et al.* [14]	91.1	91.7	91.8
Proposed Reg-CNN	**94.52**	**91.9**	**96.8**

The validation of results is done using the confusion matrix. A confusion matrix is created to visually grasp the outcomes of a classification task in order to receive a summary of the findings. The confusion matrix is shown in Fig. 11.

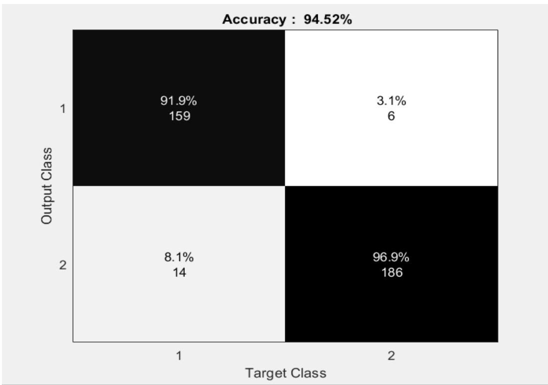

Fig. 11. Confusion matrix.

It summarizes the right and wrong predictions according to class. It demonstrates how the classification model becomes confused while making predictions and provides insight not only into the volume of errors produced but also into the type of errors made. The confusion matrix is generated by considering temperature parameters which is recorded for 365 days. The threshold value is set to 27°, with the consideration that if it is below 27°, the soil will be wet and the light intensity will be low; if it is above 27°, the soil will be dry and the light intensity will be high. When the soil moisture detected is low the water is supplied by turning on the motor and turn off the supply when moisture is high.

V. CONCLUSION

In this paper a deep learning SAS model is developed with the help of AU controller and IoT. This design can be implemented in every large-scale farm since IoT system and decision-making algorithm is combined. The embedded hardware that is designed in this paper helps in collecting the data from different sensors like temperature, CO_2, O_2, and soil moisture. The SAS model designed is very much useful for coconut, palm oil, mango etc. farming conditions. The dataset is created by collecting the data from sensors utilized. The dataset which is stored in cloud server is analyzed using CNN model. The analysis tries to help other large farms in terms of soil conditions and temperature conditions for cultivation of different crops. The accuracy metrics shows how far the data collected by our hardware system in crop land is suitable for other farm lands. The dataset is considered for performing the experimental evaluation. The regression network that is used in CNN performs well and prediction of data achieves higher rate of accuracy when compared with other classification models. The overall results and analysis of the proposed models help the farmers to improve the quality of the agri-systems. The yearly analysis of climatic conditions and the soil conditions are very much useful for effective cultivation. Along with data analysis, security systems like finger entry to farm, GSM alert system helps the farmers to note the updates in their absence. Only 94.2% of the system was accurate. Inappropriate diagnosis was the cause of the remaining error. The methodology is designed for generalized purposed of cultivation, further need to investigate and analyse the data for particular crops like tea crop, wheat crop etc. In future the data can be analyzed by creating different changing probabilities and finding the best set of data that improves the farming conditions. The farming need to be done automatically without intervention of human whenever humans are not required.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization: N.R.Y., V.R.M., S.K.P., and K.R.C.; Methodology: S.R.B., H.K.J., S.C.B., and A.K.Y.; Data Collection: V.R.P., M.M., and V.R.R.C.; Data Analysis: N.R.Y., H.K.J., and S. M.; Data Interpretations: N.R.Y., H.K.J., and S.C.B.; Writing-Original draft preparation: N.R.Y. and H.K.J.; Writing-review and editing: K.R.C. and V.R.R.C.; Supervision: N.R.Y.; All the authors have read and approved the final version.

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