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AI Driven Greentech Innovation in Agriculture

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Abstract— **Agriculture is a primary concern of every developing nation. But most of the processes involved in agricultural sector are still orthodox and inefficient. Though the technology is improving day by day, it is high time to incorporate technology innovations into the field of agriculture for better productivity and resource utilization. We propose an intelligent farming technology with the aid of Internet of Things (IoT) and Machine Learning to make various farming techniques smarter and efficient. Various sensors were deployed in the fields to remotely monitor the parameters of soil, water and air. The sensed information is fed to an Android app and it will process the data and alert the farmer if any unusual events occur. We are also using convolutional neural network for detecting various diseases affected by the plants. Experimental results validate that our model can be used for efficient utilization of agricultural resources like water and fertilizers and thereby improve the productivity and profit.**

Keywords—Internet of Things, Smart farming, Machine Learning, Plant disease identification, IoT in Agriculture.

I. Introduction

Agriculture is one of the primary concerns of any developing nations. But due to various tough climatic conditions and increased count of plant diseases, farmers find it hard to survive with the existing traditional farming methods. Since the production of food all over the world is reducing day by day, it is high time to focus on implementing new farming techniques. Internet of Things (IoT) and Machine learning can play a vital role in this scenario.

Internet of Things is a networked collection of sensors and devices managed by a centralized or decentralized architecture. The sensors are usually deployed in the target environments and it will collect required data [1]. This gathered data is fed to a central coordinator which will process the data and initiate suitable actions with the help of actuators. The typical IoT system architecture [2] is shown in Fig. 1.

The application of machine learning in agriculture can improve the food security and productivity. Species breeding and recognition, soil management, water management, yield prediction are the various applications of machine learning in agriculture. One of the main causes of decrease in production is the disease affected in plants. The most important thing in successful farming system is diseases identification in plants. Generally recognizing diseases symptoms in plants using the naked eye of farmer is a difficult task and requires continuous monitoring. Machine learning is an apt technology for disease detection in plants. By observing leaf of the plant, plant diseases can be identified. The detection of diseased plant leaf can be done with the aid of digital image processing. CNN classifier is used to detect diseased plants with high accuracy. CNNs consist of convolutional layers, that are set of image filters elaborated to images or feature maps together with other pooling layers. Feature maps are extracted through convolution and other processing layers repetitively in image classification.

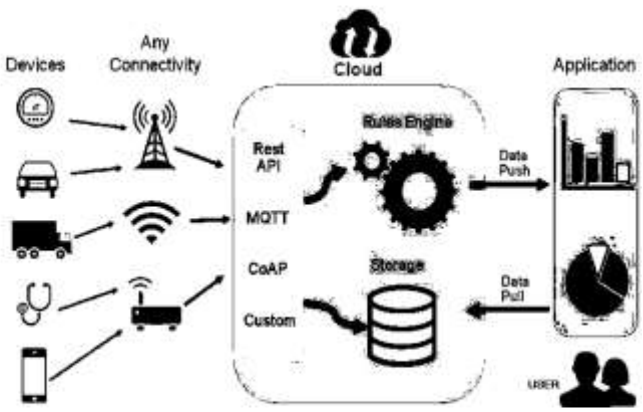

Fig. 1. IoT Architecture

The application fields of IoT and ML are drastically increasing day by day from personal applications to industrial applications. Presently IoT and ML is applied in various sectors such as transport, health, home automation, smart cities, agriculture, education etc. Our project is focusing on in-cooperating various IoT techniques and ML in agriculture sector and thereby making the farming process smarter.

The traditional farming system performs various actions like ploughing, sowing, watering, fertilizing and monitoring of plants manually. This requires huge human effort and time. Farmers were unaware about various diseased plants. We propose a model to address these challenges with the help of Internet of Things, Machine Learning and mobile application. Our aim is to not only automate the farming process but also the efficient utilization of resources.

Various objectives of our proposed model are:

1. To develop a module to remotely sense the presence of fire in the field.
2. To develop a module to monitor the quality of air by analyzing the content of Carbon Monoxide (CO).
3. To model a smart watering system based on weather reports.
4. To develop a model to recognize species and diseases in the crop leaves.
5. To design a module to monitor the moisture content in the soil and thereby initializing the watering process.
6. To develop an Android app for the farmer to remotely monitor and actuate the farming process.

This paper is organized as follows: Section II describes the related works, section III discusses about our proposed model, section IV describes the implementation details and results. Finally, the conclusions are discussed in Section V.

II. Literature Review

We have analyzed the various existing works in the area of smart farming using IoT and Machine learning.

Masrie et al [3] proposed a system for detecting the presence the presence of Nitrogen, Phosphorous and Potassium of the soil using optical transducer. It contains of three LEDs that acts as a light source and uses a photodiode as a light detector. The light from LED is absorbed by the nutrients and the remaining light is transformed to current with the help of a reflector. In this model an Arduino microcontroller was used to operate the LEDs. Their experimental evaluation proves that NPK content in the soil can be determined with the help of optical transducer. Sowmiya et al [4] proposed a system which can be used to improve the cultivation of crops in farming. The pH rate, Temperature, water level can be monitored using a 8 bit PIC 16F877A micro controller. LM35 is used for monitoring the temperature. Alerts can be sent through SMS.

Andac et al [5] proposed a system that aims to deliver a method by which any agriculture enthusiast whether it be a farmer or a gardener can monitor the conditions of the soil easily. The system checks for the pH, humidity and temperature of the soil. The microcontroller used it the Photon which has an in-built Wi-Fi function. The battery pack is 2000mAh. The solar panel used is weather sealed. The soil temperature sensor is SHT10 (it also measures the moisture), SEN0161 is the pH probe. The app is created with node.js with the database being PostgreSQL of Heroku. The advantage of the system is that it can measure the soil condition periodically and send the data to the cloud. Abdullah et al [6] proposed a model which uses STM32L152RE MCU to take samples from sensors and transfers that to mobile. DS18b20 temperature sensor is used to sense temperature and it works on Dalla's wire protocol. The system is powered using 1.5v battery. Its limitation is that it is needed to be recharged for every 30 days. The advantage is that MCU used has low power consumption and it can be cost effective. Ravi et al [7] proposed a model that contains an ESP8266 microcontroller and a moisture sensor that utilizes Losant platform. Moisture Sensor Kit is perceived using Node MCU development board. It has a soil moisture sensor module and an ESP8266 Wi-Fi module wrapped on the development board. This sensor module is connected to comparator called LM393. When the soil becomes dry, it provides an active-high (H) level output and an active-low output is given when the soil is wet. This output is fed to one of the I/O terminals of the micro-controller. Power supply is provided using a micro-USB cable. It is a low-cost system which monitors the soil moisture continuously.

Adil et al [8] proposed a model in which the elements in the soil like phosphorous, potassium and nitrogen are detected and are collected. This model uses a software application to engage the data and help the clients to identify which crop is to be planted in that soil. It alerts the user when a match is found between soil data and crop data. To use the developed software easily, this model incorporates a mobile app. The advantage of this model is that it will immediately notify the farmer. It alerts which crop to be grown in a particular soil. But it needs manual calculation and data collection.

Rahul et al [9] proposed an IoT based system which consist of temperature sensor, pH sensor, air quality sensor, water volume sensor, humidity sensor and soil moisture sensor. All these sensors gather analog data and the central coordinator converts it into digital value. Based on the digital value analysis, necessary actions are initiated through Wi-Fi communication. Halil et al [10] proposed a system for disease detection on tomato leaves using deep learning. The disease of the plant is automatically or manually detected by running deep learning algorithm in real time on robot. Disease detection is also possible by taking close-up photographs of plants using sensors which is built in fabricated greenhouse. The identified disease can change the tomato plant leaves and can be viewed with RGB cameras. The challenge of the implementation is the selection of deep learning architecture. This is solved by testing two deep learning network architecture, Alex Net and Squeeze Net. The training and validation of both networks were done on Nvidia Jetson TX1. It uses ten different class including healthy images.

Monzurul Islam et al [11] proposed a system for detecting the diseases in potato by using multiclass support vector machine and segmentation. Here the disease is diagnosing by integrating image processing and machine learning from images of leaves. There is an available database of plant image called 'Plant Village' which classifies the diseases on potato plants. The inclusion of SVM defend disease classification over 300 images and it will be highly accurate. Sruthi et al [12] proposed the various stages of detection of disease in plants. It is a study of classification of machine learning for detection of disease in plants. The disease of plants is detected by analyzing it's parts like leaf, stem and root. It also makes clear that the accuracy provided by the convolution neural network is high and it can detect the large number of diseases.

Parul et al [13] introduces an algorithm for detecting the disease in large number of plants using machine learning. The proposed algorithm can train itself, i.e. with respect to the usage it can increase the accuracy. The main advantage is that it can run on any platforms like smartphones. The farmers who are not expert can easily and effectively manage diseases. Jyothi et al [14] introduced a system for disease detection in plants which is easier compared to manual method. The affected leaf is detected using machine learning. The camera will take the images of leaves and these leaf images are then processed and analyzed using image processing methodologies. Thus, the yield can be increased using this technique by detecting the diseases and by rectifying it.

From the review, it is clear that there is no standard model which will address all these challenges in agriculture. So, we aim to propose a smart farming system to manage and monitor various farming processes in an efficient and effective manner with the aid of IoT and ML.

III. Proposed System

The proposed smart farming system consists of the following 4 modules: Android app module, ML module, sensors module and a central coordinator module. The system is modelled [15] in client-server architecture. The sensors are placed in the agricultural field to sense the required parameter. The sensors sent the data to the central coordinator which is managed by an Android application. This data is sent to a cloud database. The mobile app analyses the cloud data and alerts the farmer if any parameter exceeds its threshold limit. Node MCU acts as the central coordinator. The user can view all the data acquired from the sensors on the app and necessary actions can be taken. The block diagram of proposed system is shown in Fig. 2.

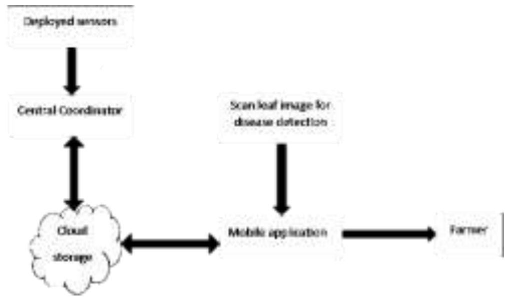

Fig. 2. Proposed Model for Smart Farming

A. Android App Module

When the Android App is started, the user is first presented with the login page. The main page shows a breviloquent version of the sensor data. Also, if any unusual spikes in the data are detected an alert is shown in this page. Along with this the latest weather information is displayed. The App will analyze the sensor information and alerts the farmers when parameter exceeds its threshold.

B. Sensor Module

The proposed model aims to collect various parameters like water pH content, moisture content of soil [16], presence of carbon monoxide in air, presence of NPK in soil etc. These parameters should be remotely sensed and the gathered information should be fed to a central data processor for further processing. The sensors used include LM393- Soil moisture sensor, MQ2 Smoke sensor and MQ9 Gas sensor.

C. Central Coordinator Module

The central coordinator is Node MCU which has powerful processing capability. The central coordinator controls and coordinates all the activities of the system. Various sensors are integrated with the central coordinator. With the help of central coordinator sensors will sense the information, and this sensed information is further processes to identify the various soil, air, water quality parameters. If any of these parameters exceeds the preset value and alert message or mail is sent to the farmer.

D. Plant Disease Detection Module

Machine learning methods are used for the identification of diseases [17]. Convolutional Neural Network (CNN) is used to detect a greater number of diseases in multiple crops with high accuracy rate. To detect diseased leaf, digital image processing is used which involves various processes like image acquisition, a noted dataset, image processing, feature extraction and classification. Image acquisition is the first stage of diseases detection where high quality images are acquired using digital cameras. A noted dataset is a knowledge-based dataset created for captured images. Image processing is the process of improving image features for the extraction of diseased area in leaves. Feature Extraction is the process of extracting various features like color, shape and texture features of diseased part of leaves. And finally, CNN classifier is used to classify diseases in plant.

The architecture diagram of the proposed system is shown in Fig. 3. Sensors for gathering the information are deployed in the field. Actuators (Water sprinklers) for watering the crops are also deployed. The sensors continuously collect field parameters and are fed to the central coordinator. The central coordinator backs up this data for further analysis. If any of these parameters exceeds the threshold limit, an alert message or email will be sent to the farmer. In case of fire, an alert will be also sent to the nearest fire station. Using machine learning technique disease detection is made possible. Farmer can take picture of plant’s leaf using the camera icon in the Android app and find whether it is healthy or not. If the plant leaf is healthy then it will display ‘healthy’ otherwise display disease of that plant’s leaf.

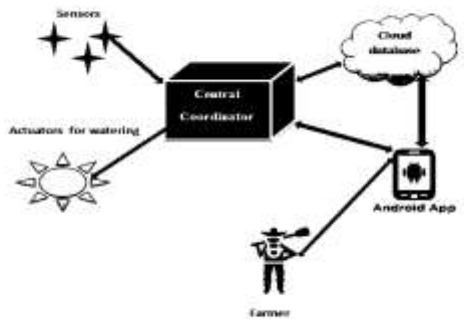

Fig. 3. Architecture Diagram

IV. System Implementation and Results

System is implemented using the microcontroller Node MCU. Various sensors are integrated with this microcontroller and the sensed information is send to Google firebase and then to Android app. Android part is developed using Android Studio using the language Java. Node MCU is used as the central coordinator of our system. The connection diagram is shown in Fig. 4.

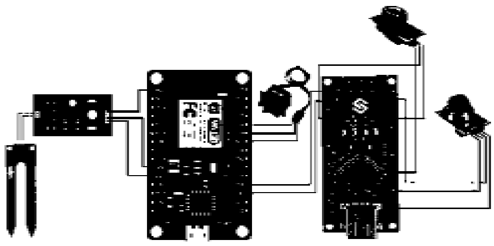

Fig. 4. Connection Diagram

A. ML model using TensorFlow with Keras

An open-source deep learning framework called TensorFlow which consist of modules for the logic and knowledge of a ML network which can be used for training to resolve a real time problem. There are distinct ways to access a TensorFlow model using pre-trained system models to train ourselves. TensorFlow Lite is integrated with tools needed to convert and run TensorFlow models on embedded, mobile and IoT devices. A network can be trained from scratch with a large data set using ConvNet. Convolutional neural network which is 48 layers deep used for image analysis and object detection is inceptionv3. It is possible to load a pretrained version of network which is trained on more than a million images from the database called ImageNet database. One of the mostly used image recognition model is Inception v3. The main feature of the model is that it has an accuracy of more than 78%. Convolutions, max pooling, average pooling, Dropout, fully connected, SoftMax are the building blocks of inception V3. Inception V3 consists of two parts: feature extraction and a classification part. Feature extraction part includes a convolution neural network and classification part contains with a fully connected SoftMax layer. That means, from the input images itself the model will extract its common features and then classify those features by comparing it with features in classification part. Schematic diagram of inception v3 is shown in Fig. 5.

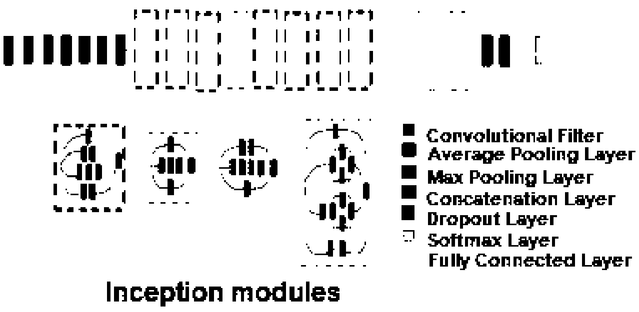

Fig. 5. Schematic Diagram of Inception v3

B. Steps of Building CNN

1. Convolution Operation: It is the first layer for extracting features from the input image and it learns the relationship between features using kernel with input images.

2. ReLU Layer: ReLU stands for the Rectified Linear Unit. The output is $f(x) = \max(0,x)$.It is used to introduce the non-linearity to CNN.

3. Pooling Layer: It is used to retain only the valuable information to process further and to reduce the number of parameters by down sampling.

4. Flattening: Flatten entire matrix into a vector so that it will be passed to the input layer.

5. Fully Connected Layer: Flatten vector after flattening is passed to input Layer an create model by combing these features. Finally, to classify the outputs there will be an activation function such as SoftMax or sigmoid.

Using Convolutional Neural Network, it is easy to recognize species and diseases in the crop leaves, following are the steps:

1. Importing Libraries: For the classification of plant disease with TensorFlow Lite various libraries have to imported.

2. Loading the data: For this a public dataset is downloaded which consist of various healthy and diseased plant leaves images. The data set contain many species of crops. Training and validation directories also be created.

3. Label mapping: From category label to category name load the mapping.

4. Transfer Learning with TensorFlow hub: Select Hub/T 2. There is an alternative with inception V3 or Mobile net.

5. Data Pre-processing: In order to get images from source folder, covering those images into ' float 32' tensors. For this, data generators are set up. Then normalize the pixel value of the image in the range of [0,1]. The input date should be of size 224×224 or 299×299 pixels.

6. Build the model: To build the model, use a non-trainable feature extractor. For getting more accuracy, it is possible to authorize fine tuning, but it is time consuming.

7. Training Model: Model is trained by validating each step with validation dataset. Accuracy can be improved using fine tuning.

8. Convert model to TensorFlow Lite: To use a model with TensorFlow Lite, first step is to convert a TensorFlow model into the TensorFlow Lite format.

Fig. 6. shows the latest whether information's displayed in the app.

Fig. 6. Weather information in Android App

Based on this weather information if there is a high chance of occurring rain on a particular day, the system will not initiate the watering process. On clicking camera button in the main page, a new page arises where we have mainly 3 options. For taking the picture of diseased plant in real time there is start camera button. There is diagnosis button to launch detection of plant disease. Its output will be either the plant is healthy or the corresponding diseases. Diseases detection is shown in Fig. 7. MQ2 smoke sensor will detect the presence of smoke in atmosphere and if it is greater than a particular threshold value, an alert mechanism is implemented for getting a notification to user and fire authority. Fig. 8. (left) shows the user needs to grant permission, that allow AgroTech to send and view SMS messages. Fig. 8. (right) shows the alert mechanism send to the farmer when smokes value is high in the field.

The model is validated [18] using decision-based testing [19]. Out of the total images, 80% were used for training the model and 20% were used for validation. Results of Inception V3 model on test dataset is shown in Table 1.

Table I. Results on test dataset

	Accuracy	Precision	Recall	F1 score
INCEPTION V3	74.4	0.72	0.66	0.69

Due to inadequacies of data availability of numerous plant diseases, the Accuracy, Precision, Recall and F1 score accuracy was calculated manually. We have integrated the IoT module and ML module together using Big bang approach. Both the modules are linked together in a single step and tested. We used decision table-based testing [20]. We have performed GUI based testing in App module, Performance testing and component testing in the hardware modules.

Fig. 7. Diagnosis result

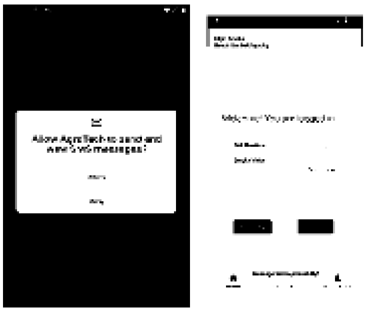

Fig. 8. Alert messaging in Android App

V. Conclusions

Our proposed smart farming system consists of an IoT module ML module and Android app module controlled by a central coordinator. The mobile application helps farmer to get information about agricultural fields and plants diseases. Using convolution neural network diseases in the crop is recognized. In mobile application there is an option for capturing image of plant's leaves. There is a diagnose button, on clicking diagnose button, output will be displayed with the corresponding disease affected by that plant. The sensors incorporated with the Node MCU identify farm status and alerts the farmer when soil moisture level, gas, smoke and temperature level reach a threshold value. Thus, our system helps the farmer not to collect soil samples and sending it to lab for checking nutrients level and there by save time also get idea about various diseases affected by plants. It also reduces human effort and thereby makes the farming more efficient.

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