Grenze International Journal of Engineering and Technology, Jan Issue

An Integrated Framework for Smart Farming using Internet of Things and Computational Intelligence

Pramod Mathew Jacob[1], Jeni Moni[2], Renju Rachel Varghese[3], Bibin Vincent[4], S Prasanthi[5] and Smitha Joseph[6]
[1-6]Department of CSE, Providence College of Engineering, Chengannur, Kerala, India
Email: pramod3mj@gmail.com, {jeni.m, renju.v, bibin.v, prasanthi.s, smitha.j}@providence.edu.in

***Abstract*—Agriculture is one of the prime sources which determines a nation's prosperity and economic growth. But most of the farmers find it difficult to survive due to the following reasons like lack of enough labors, inappropriate and traditional methods are followed to monitor agricultural fields and plant growth etc. As technology has evolved, it is possible to automate the various phases of farming activities. There are many standard sensors available to remotely monitor the soil moisture content, pH content, fire detection in the field, intruder detection etc. All these sensors sense the information and is fed to a central coordinator which will process the data and initiate necessary actions. All these are done over internet and thus the concept can be called as Smart farming using Internet of Things. It is also possible to analyze the image of plant leaf to identify the various plant dis-eases with the help of Machine Vision. Our model thus reduces the farmer's overhead using IoT and computational intelligence.**

***Index Terms*— Smart farming, Internet of Things, Machine Vision, Machine Learning, Intelligent Computing.**

I. INTRODUCTION

Agriculture is one of the prime concerns of any developing nation as it may enhance nation's growth and prosperity. Most of the farmers are still following the ancient modes of farming which is inefficient and uneconomical in most of the cases. As technology is booming up in every sector, its high time for agricultural sector to focus on integrating technology. The ancient farming process include various process like sowing, ploughing, fertilizing, watering and monitoring of plants in a periodic basis. This demands huge human effort and time. Farmers may not be always aware about distinct plant diseases and crop diseases. The dis-tinct sort of challenges faced by the farmer is pointed below:

- It is not possible to directly measure the soil mineral content.
- It is a time-consuming procedure to send the soil sample to the labs and collecting the results.
- Automated water pumping systems for plants during rainy season may lead to decaying of plants.
- The plant growth is affected due to various pollutants in the air.
- Unexpected fire may destroy the crops.
- The improper watering cycles in a farm field may lead to enormous wastage of water.
- Difficulty in recognizing plant species and crop leaf diseases.

Grenze ID: 01.GIJET.8.1.117

Internet of Things (IoT) can take a lead role in the agricultural sector and thereby makes the farming process smarter. Smart farming is the term used for integrating IoT into the agricultural sector. Various farming activities like soil moisture detection, water level detection in the field, weather conditions, pH level, soil nutrient level, fire detection etc. can be done remotely with the integration of Internet of Things.

Internet of Things is simply a networked collection of components or devices connected over internet. These things can be devices like sensors, actuators etc. All these things are connected to a central coordinator module like an Arduino, Raspberry PI, Node MCU etc. Every device should have a unique identifier. It us-es IPv6 addressing for the same. The typical architecture of an Internet of Things [1] is illustrated in Figure 1.

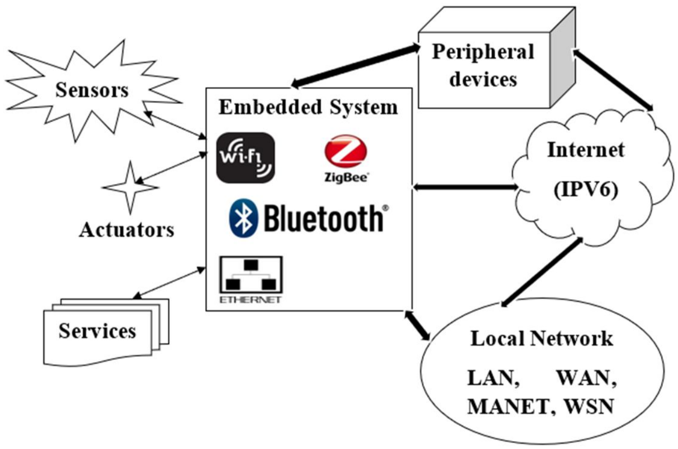

Figure 1: Architecture of IoT

A typical IoT model consist of a collection of networked components and software embedded in physical components. The software embedded physical component is usually considered as a central coordinator module. The central coordinator module can be a microcontroller or a microprocessor. Arduino, Node MCU, Intel Galileo and Raspberry PI boards are some of the most widely used boards as central coordinator. Real time data is collected with the aid of different sort of sensors. The central coordinator collects these data and then process it ac-cording to the stored program and initiates command to the actuators to perform necessary actions.

A distinct class of sensors are available in the global market a long back be-fore. But the intervention of Internet of Things (IoT) geared up the evolution of real time sensors. IoT based systems performs various sort of intelligence with the help of data delivered by the sensors. IoT systems gather real time data through sensors and push it to the central coordinator. The coordinator module analyzes and processes these data and initiates suitable decision making based on the embedded software code. The actuators perform the actions to be initiated and thus the whole system autonomously operates and makes the system 'smarter'.

The various sensor classes include Temperature sensors, Proximity sensors, Pressure sensors, Water quality sensors, Air quality sensors, Smoke detection sensors, Chemical sensors, Gas sensors, Level sensors, Infrared sensors, Image sensors, Motion detection sensors, Optical sensors, Gyroscope sensors, Humidity sensors and Accelerometer sensors. There are even many other domain specific sensors available in the market. These sensors are considered as the prime input de-vice in an IoT model. Sensors are even termed as 'transducers' in some literature. The characteristics of a good transducer includes precision, linearity, sensitivity, accuracy, wide dynamic range and less physical size.

An actuator operates in the reverse mode of a sensor. Actuator converts electrical signal into physical action. There are different categories of actuators avail-able like Pneumatic actuator, Electrical actuator, soft actuator, Hydraulic actuator, Mechanical actuator, Thermal or Magnetic actuator etc. Actuators can be considered as an output device in an IoT model.

IoT consist of both hardware components and software modules. Hardware components are integrated together to form the IoT system. Software modules are embedded in the hardware. It uses distinct class of software architecture pat-terns like client-server, publish-subscribe, Representational State Transfer (REST) and Peer-Peer patterns. The pattern selection strategy is different for different IoT applications which mainly depends on heterogeneity and security. The work flow of an IoT system can be illustrated using Unified Modelling Language or Data Flow diagrams [2].

Internet of Things occupies a major space in the digital world where people like to remotely control their objects and things using internet applications. Though the things and devices involved has heterogenous nature, it is a tedious task for the software architect to model an IoT application for a domain. The various challenges in designing an IoT based system is listed below:

- Compatibility and interoperability of heterogenous devices.
- Lack of standardization in device Identification and authentication
- Difficulty in integrating IoT applications with IoT platforms
- Difficulty in handling the unstructured, unformatted data
- Ensuring reliable connectivity between devices.
- Information security and privacy concerns.

Industrial automation and home automation are acquiring its place in this modern technology era. Internet of Things can play a significant role in this regard. IoT not only supports automation but also provides the facility to control components over internet. Though the IoT devices consist of both hardware and software modules high priority should be given in modelling and validating an IoT product. Improper models may result in inefficiency or system failures or even some unexpected disasters. The importance of software modelling is to identify the best suitable architectural pattern for a particular problem. For a single problem, there will be different models available. The design architect should choose the pattern which works well with the target environment in an efficient and effective manner. In some cases, there will not be any standard design metaphor available where the designer has to model a new metaphor or should use the combinations of existing patterns. One of the critical challenges in choosing the software design pattern for an IoT application is its heterogeneous nature. Also, the nature of the pattern should be light weight as most of the IoT devices works on remote areas with power constraints. In this regard, there should be a proper se-lection criterion to choose the best software pattern for IoT applications.

After successful design and modelling the IoT product may be developed. A typical IoT product consists of hardware components, web application or a mobile application and a cloud database to store the gathered data. The hardware components are monitored and controlled by the software modules. So, in fact software module can be considered as the nervous system of IoT. Because it controls and coordinates all the activities inside a typical IoT application. An error or a defect in the code may lead to malfunctioning of the actuators and thereby results in system failure. Thus, there is need of a common testing procedure to be followed for validating hardware, software and communication layers of IoT product. There is large class of software testing tools available. Most of the soft-ware testing tools are script based. The performance, efficiency and user-friendliness of these testing tools differs from tools to tools. In this scenario, there is a need of a selection model to choose the best software testing tool for IoT product testing. Thus, a typical IoT based system requires a seasoned software architectural pattern supplemented by a well-defined set of testing and validation procedures.

Internet of Things (IoT) based smart farming system is modelled for monitoring and managing the agricultural field with the aid of various sensors like soil moisture, temperature, humidity, light and Smoke detection and thereby auto-mating the various farming activities. The farmers can remotely monitor and manage their farm fields using mobile application or through a web page inter-face. This will make the farming activities more efficient and easier than that of the conventional approach. Smart farming can be extended to even the next level like automating the yielding process, packaging, transporting to the retailers etc. Considering the environmental and economic aspects, IoT based agriculture can offer huge benefits including efficient usage of water and fertilizers, optimized in-puts and treatments etc.

The rest of the paper is organized as follows: Section 2 discusses the related works whereas sections 3 & 4 describes the proposed system and its implementation. Finally, the conclusions are mentioned in section 5.

II. RELATED WORKS

This section provides the analysis of various existing smart farming models proposed by various developers or researchers which has significant relevance in this modern era of intelligent farming. The majority of the systems consider simi-lar metrics and uses same sensors to detect the soil moisture level and nutrient contents in the field. Machine vision is used to identify the plant diseases by scanning the plant leaves. They have used various microcontrollers and micro-processor systems to integrate the various sensors, actuators and embedded soft-ware. This section provides the brief overview of the most relevant 25 works in the area of intelligent or smart farming.

Masrie et al [3] designed a smart farming system for measuring the presence of Nitrogen, Phosphorous and Potassium level of the soil in the farm field with the usage of optical transducer. It consists of three LEDs which acts as the light source and a photo diode is used as light detector. The light emitted from these LEDs are absorbed by the nutrients in the soil and the excess light energy is con-verted into current with the aid of a reflector. Arduino microcontroller is sued as the central controller and also the power source for the LED. Their exploratory assessment demonstrates that NPK content in the soil can be measured with the assistance of optical transducer.

Abdullah et al [4] proposed a smart farming system which utilizes STM32L152RE Microcontroller unit to fetch samples from distinct sensors and then transfers those fetched information into the mobile phone. DS18b20 temperature sensor is utilized to gauge temperature and it uses Dalla's wire protocol for its operation. The attached pH sensor consists of two electrodes; first one for pH and the other for soil moisture estimation. For soil moisture estimation, it uses an inverse relation between both soil resistance and soil moisture. A 1.5V battery system is used as the power source for this system. One of the main limitations of this model is that the battery needs a regular recharging in every 30 days. Low power consumption and cost effectiveness are the key advantages of this model.

Andac et al [5] devised a framework that can be used by any farmer or a grounds-keeper to lively monitor the field conditions. The proposed framework constantly checks the humidity, temperature and pH level of the soil in the field. Photon embedded with a Wi-Fi module is used as the microcontroller for this system. 2000mAh battery package is used as power source. A weather proof solar powered battery is attached. The soil temperature sensor used is SHT10 (it also estimates the moisture level of the soil), SEN0161 is used for testing the soil pH lev-el. This application is developed with node.js along with the dataset in PostgreSQL of Heroku. The main advantage of this model is that, it can accurately measure the soil condition periodically and send the information to the cloud storage.

Adil et al [6] devised a model where which the nutrient components in the soil like phosphorous, potassium and nitrogen are analyzed and its involvement ratio is gathered. This model consists of mobile or web application to constantly process the gathered information and later provides assistance to the farmers to plan which crop is to be planted in that particular region during this weather condition. It provides an alert message or email to the farmer when there arises a match be-tween the gathered soil information and crop information. This Android application provides a quick intimation to the farmer about the current field conditions. The prediction model predicts which crop can be cultivated in that specific soil conditions. But it needs manual estimation and information analysis which is one of the major limitations of this model.

Ravi et al [7] proposed an intelligent farming system which consist of an ESP8266 microcontroller and a set of sensors. The sensors include soil moisture sensor which uses Losant platform for its operation. The soil moisture sensor module is integrated with the NodeMCU board. This sensor module is associated with a comparator called LM393. At a particular threshold point where the soil becomes dry, it generates an active-high (H) level output. The system generates an active-low output when the soil is in wet condition. This output variation is taken care of to one of the I/O terminals of the miniature regulator. Power supply is provided using a mini-USB cable. This is an economical model to constantly monitor the soil moisture level in the farm fields.

Lily et al [8] proposed an Android application which runs on smart interactive devices to constantly monitor the soil moisture level. Various sensors are deployed in the field and this sensed value is later fed to the Raspberry PI. The Android ap-plication displays these data on the user interactive screen. The alert notification for water supply is generated by lighting up an LED. The outcome of this model is an Android application which constantly shows the percentage level or value of soil moisture content. The sensor feds analog value which is later converted to digital using a DAC. From this gathered information, farmers can remotely monitor and manage the watering of plants using various actuators like water pumps and motors. The history of these data is stored in the cloud database.

Sharma et al [9] proposed a smart farming system which contain various digital sensors that are used for testing the soil in real time with minimum efforts and maximum accuracy. A data acquisition system that can be remotely accessed or controlled are deployed at wide locations. A handy device is devised to identify soil moisture content and these data is constantly uploaded to the cloud. The system includes a microcontroller device, pH sensor, EC sensor and color sensor. The readings of these deployed sensors are later transmitted to a mobile application via Bluetooth module. The mobile application uploads these gathered data to the cloud for further data processing and system analysis. The prime use of their model is to make a portable system to identify the pH level, color texture, Electrical Conductivity of soil.

Pramod et al [10] developed an Android app [9] using IoT and Machine vision. Their model uses various sensor like temperature, humidity, smoke and soil moisture. The sensors fetch the required data and will store in the central coordinator. The Android application process these data and provide updates to the farmer. It also has a leaf disease prediction module which will scan the leaf of a crop. The Android app process the leaf image and predicts the leaf disease with an accuracy of almost 70%. Their model has much relevance in smart farming applications.

III. PROPOSED MODEL

Our proposed model is named as AgroTech smart farming system. AgroTech smart farming system consists of the following 4 modules: Sensor module, Central coordinator module, Machine Learning (ML) module and Android app module. The various sensors are deployed in the agricultural fields to sense the soil-parameters. The sensors collect these data and will fed the same to the central coordinator module for further processing. The central coordinator up-loads this data to a cloud database. The Android application module analyzes these stored cloud data and check whether any soil-parameter is varying from the threshold. If any variation is noted, an alert message is sent to the farmer. NodeMCU is used as the central coordinator module in this case. The users (farmers) can create an account in the Android application and can monitor all the re-quired data that is collected from various deployed sensors. The user can control the actuators via Android app and thereby makes the system much user friendly and smarter. The block diagram of proposed system is shown in Figure 2.

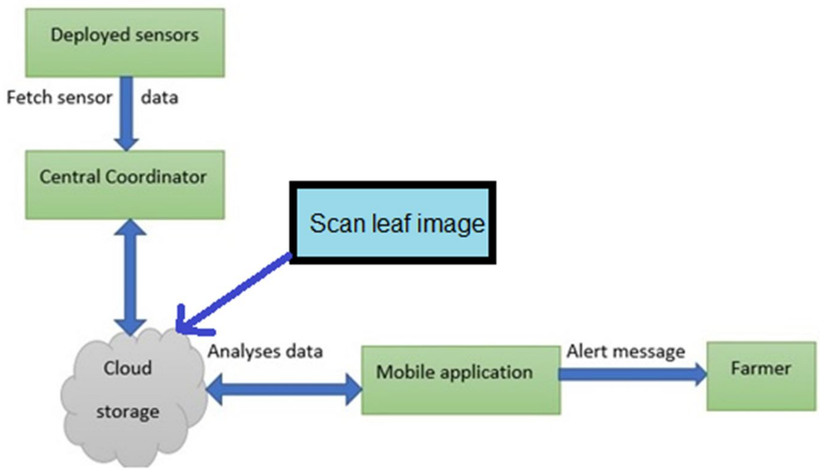

Figure 2: Block diagram of AgroTech Smart Farming

A. System Analysis

The Smart Farming System is expected to meet the following requirements. REQ denotes requirement id.
REQ 1: Monitor the moisture content in the soil
Description: To perform constant monitoring, sensors are used to detect the moisture content of the soil.
REQ 2: Constantly check the weather updates and thereby initiate the watering process.
Description: The mobile application will constantly check the weather information from various trustable applications. Based on the analysed weather results, the proposed system will initiate the watering forces. If there is a high chance of occurring rain on a particular day, the system will not initiate the watering process.
REQ 3: Check the quantity of NPK contents in the soil.
Description: Presence of soil nutrients like Nitrogen, Potassium, Phosphorous will be sensed by deploying a suitable sensor in the field. This will provide an accurate information to the farmer about the soil nutrient levels.
REQ 4: Develop an Android application.
Description: To develop an Android application to aid the farmer to remotely monitor the soil moisture level, nutrients contents, presence of carbon monoxide in the field, pH value of the water in the field etc. The collected information is continuously analysed. If any value goes beyond the threshold value, the farmer will get an alert message.
REQ 5: Continuously monitor the quality of soil.
Description: A pH sensor will be deployed in the field (in case of paddy cultivation) to sense the pH value. If the pH value exceeds the threshold an alert message will be initiated to the farmer through mobile app.
REQ 6: Continuously monitor the quality of air.
Description: The presence of toxic gases like carbon monoxide will be sensed using a suitable sensor. Alert message will be given to the farmer if it exceeds the pre-setted threshold value.

REQ 7: Recognizes species and diseases in the crop leaves.
Description: Using CNN classifier automatic detection of all types of diseases in crop is made possible. CNN classifier can detect a greater number of diseases with high accuracy and thereby act as a helping hand to farmer.

B. System Modules

i) Android App

The Android app is installed in the farmer's phone. When the app is launched, the user has to login into their account. After successful login, the farmer is directed to the home page of the application. It shows a breviloquent mode of the sensor data. If there is any variation in the threshold, an alert message is dis-played. The hamburger menu in the main page redirects the user to different pages such as notifications, alerts, help, reference values, data history, actuators and settings. The Android app will constantly analyze the sensor values and periodically alerts the farmers when the sensed parameter exceeds the threshold.

ii) Sensor module

The sensor module is considered as the key input module of this system. A typical smart farming system requires various data like the water content or moisture level in the farm field, pH level in the soil, the amount of carbon monoxide in the atmosphere of agricultural field, the ration of NPK content in the soil etc. The listed parameters should be remotely sensed from the farm fields with the aid of sensors and mobile application. The central coordinator will later process these data and initiates suitable action with the support of connected actuators to the system. There are distinct standard sensors available in the market to sense these parameters like LM393-Soil moisture sensor, pH sensor, Optical transducer, MQ2 Smoke sensor and MQ9 Gas sensor.

iii) ML module

Plant diseases can be identified by crossly examining the plant leaves with the help of machine learning techniques. Convolutional Neural Network (CNN) is used in our model as it has high accuracy and is able to detect greater number of diseases of distinct crops. Digital image processing techniques are used to detect the disease affected leaf. Image processing includes various phases like image acquisition, dataset annotation, feature extraction and later classification [13]. Based on the machine vision analysis, the system will alert the farmer about the decaying of plants due to various crop diseases.

iv) Central coordinator module

NodeMCU microcontroller is used as the central coordinator module in this smart farming system. NodeMCU controls and coordinates all the functionalities of the farming system. As Raspberry PI embedded with Raspbian operating system is also used to train the system using machine learning techniques. Raspberry PI has better processing capability than that of NodeMCU which is the microcontroller unit. NodeMCU collects the sensor parameters from the farm field and sent to the Raspberry PI for further processing. The various soil, air and water quality parameters are analyzed. If any of these parameters exceeds the threshold value a message or alert email is sent to the farmer.

Smart farming system is implemented using the Node MCU microcontroller where which the various sensors are connected. These sensors fetch the relevant data and will send it to Google firebase and later to the Android application. During sowing process and plant growing stages, farmers get the nutrient values and water level in the filed through their mobile application. In case of fire occurrence in the farm field, alert message is sent to both fire force authority and farmer with the location. Various sensors connected to Node MCU is shown in Figure 3.

IV. IMPLEMENTATION AND RESULTS

The proposed system is implemented using both hardware and software modules. NodeMCU is used to connect all the sensors whereas Android application is developed for the farmers to remotely monitor and control the farm field. The hardware connection diagram of various sensors and actuators used in AgroTech smart farming system is illustrated in Figure 4.

Hardware pin connection details for the sensor module is listed below:

[1] Connect Rx pin of Node MCU with Tx pin of Arduino using female - male jumper wire.
[2] Connect Tx pin of Node MCU with Rx pin of Arduino using female – male jumper wire.
[3] Connect GND of soil moisture sensor with GND of Node MCU using female – female jumper wire.
[4] Connect VCC of soil moisture sensor with VCC of Node MCU using female – male jumper wire.
[5] Connect A0 of soil moisture sensor with A0 of Node MCU using female – male jumper wire.
[6] Connect GND of servo motor with GND of Node MCU using female – female jumper wire.

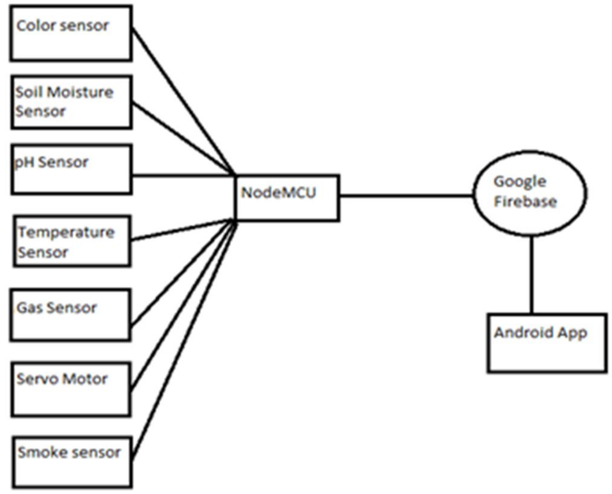

Figure 3: Sensors and Actuators in AgroTech

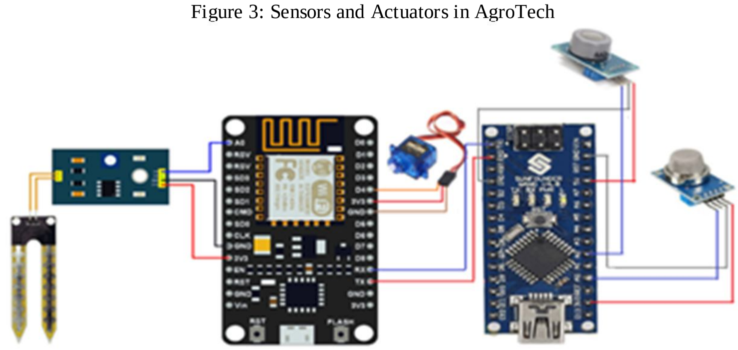

Figure 4: Hardware connections of AgroTech

[7] Connect VCC of servo motor with 3v3 of Node MCU using female – female jumper wire.
[8] Connect A0 of servo motor with D4 of Node MCU using female – female jumper wire.
[9] Connect GND of smoke sensor with GND of Node MCU using female – female jumper wire.
[10] Connect VCC of smoke sensor with 3v3 of Node MCU using female – female jumper wire.
[11] Connect A0 of smoke sensor with A0 of Arduino using female – female jumper wire.
[12] Connect GND of gas sensor with GND of Arduino using female – female jumper wire.
[13] Connect VCC of gas sensor with 5V of Arduino using female – female jumper wire.
[14] Connect A0 of gas sensor with A2 of Arduino using female – female jump-er wire.

The illustration of the working of our Android application is explained below in Figure 5. When the app is started, user is first entered to the login page. Then the user is redirected to choose one of the two options for login. By using Google sign in or Email account. The user can use an already existing account or can add another account. Once the user logged in successfully, entered into the main page of the app which gives all the sensed information. The mobile application will constantly check the weather information from various trustable applications. Based on the analyzed weather results and soil moisture value, system will initiate the watering forces. After successful login, app shows the main page which contains soil moisture value and smoke value in the agricultural field.

On clicking weather button, the app will be redirected to new page showing current weather conditions. Figure 6 shows the latest whether information's displayed in the 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 selecting diseased plant picture from gallery using select photo button. 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. Figure 6 (right hand side) provides the illustration of these process.

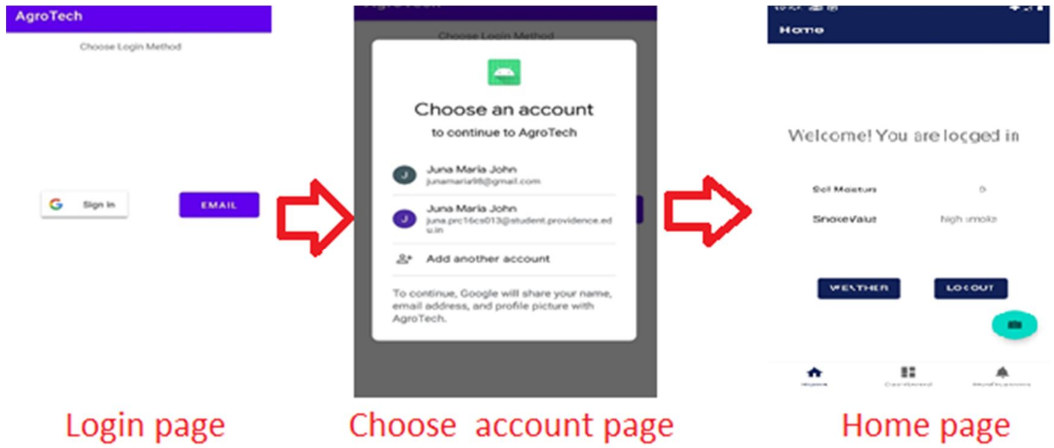

Figure 5: Android app view – Loading Home page

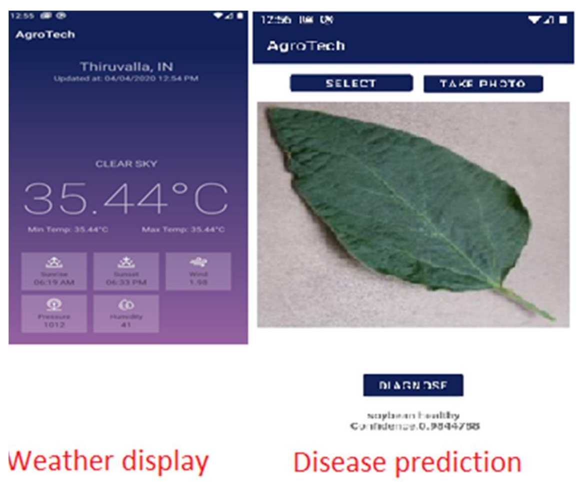

Figure 6: Weather prediction and Disease Detection

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. Consequently, AgroTech keen cultivating framework comprises of a sensor module and a mobile application constrained by a central module. The mobile application assists farmer with gathering data about farm fields and plants. Utilizing convolution neural organization illnesses in the harvest is perceived. The sensors joined with the Node MCU recognize ranch status and alarms the rancher when soil dampness level, gas, smoke and temperature level arrive at a limit esteem. Accordingly, this framework helps the farmer not to gather soil tests and sending it to lab for checking supplements level and there by save time additionally find out about different illnesses influencing plants. It additionally lessens human efforts. The model is validated using various software [12] and hardware testing techniques [13] used in Internet of Things based systems.

V. Conclusions

Agriculture plays a key role in the development and progress of any nation. By the intervention of technology into the agricultural sector, farming and activities related to cultivation became much easier and smarter. Internet of Things (IoT) is the real game changer by making the various smarting activities more efficient and easier. IoT provides the facility to the farmer to remotely monitor and man-age the agricultural field activities like sowing, watering, fertilizing and even monitoring the crop yield. All these activities can be controlled and coordinated using a mobile application from a remote location. Machine Learning can be also used to identify the plant diseases by analysing the image of the plant leaf. Thus, Internet of Things and Machine Learning makes farming process more efficient and economical.

ACKNOWLEDGMENT

We wish to express our sincere thanks to Mr. Sravan Suresh, Ms. Juna Maria John, Ms. Parvathy Nandakumar and Ms. Parvathy Nath for all the support offered in implementing this project work.

REFERENCES

[1] P. M. Jacob, P. Mani, S. Simon, R. R. Varghese, K. John and N. Aniyan, "An Integrated Blockchain Approach to Model Secure Internet of Things based Systems," 2020 International Conference on Data Analytics for Business and Industry: Way Towards a Sustainable Economy (ICDABI), 2020, pp. 1-5,

[2] P. M. Jacob, Muhammed Ilyas H, J. Jose and J. Jose, "An Analytical approach on DFD to UML model transformation techniques," 2016 International Conference on Information Science (ICIS), 2016, pp. 12-17.

[3] M. Masrie, M. S. A. Rosman and R. S. a. Z. Janin, "Detection of Nitrogen, Phosphorus, and Potassium (NPK) nutrients of soil using Optical Transducer," in Proceedings of the International Conference on Inventive Research in Computing Applications (ICIRCA 2018), Putrajaya, Malaysia, 28-30 November 2017.

[4] E.Sowmiya and S.Sivaranjani, "Smart system Monitoring on soil using Internet of Things (IoT)," International Research Journal of Engineering and Technology (IRJET), vol. iv, no. 02, pp. 1070-1072, 2017.

[5] A. Demir, "Remote Monitoring of the Soil Quality with the Internet of Things," ECE Capstone Project, 2017.

[6] A. Na, W. Isaac, S. Varshney and K. E, "An IoT based system for remote monitoring of soil characteristics," in 2016 International Conference on Information Technology (InCITe) - The Next Generation IT Summit on the Theme - Internet of Things:Connect your Worlds, Noida, 2016.

[7] R. K. Kodali and A. Sahu, "An IoT based soil moisture monitoring on Losant platform," in 2016 2nd International Conference on Contemporary Computing and Informatics (IC3I), Noida, 2016.

[8] A. Usman and N. K. Verma, "Internet of Things (IoT): A Relief for Indian Farmers (Stage II)," IEEE Global Humanitarian Technology Conference (GHTC), San Jose, 2018.

[9] P. Sharma and D. V. Padole, "Design and implementation soil analyser using IoT,", International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS), Coimbatore, 2017.

[10] P. M. Jacob, S. Suresh, J. M. John, P. Nath, P. Nandakumar and S. Simon, “An Intelligent Agricultural Field Monitoring and Management System using Internet of Things and Machine Learning,” in 2020 International Conference on Data Analytics for Business and Industry: Way Towards a Sustainable Economy (ICDABI), 2020.

[11] Jacob, P.M., Mani, P., “A performance estimation model for software testing tools”, International Journal of Engineering and Advanced Technology, 8 (4), pp. 248-253, 2019

[12] P. M. Jacob, Priyadarsini, R. Rachel and Sumisha, "A Comparative analysis on software testing tools and strategies," International Journal of Scientific & Technology Research, vol. 9, no. 4, pp. 3510-3515, 2020.

[13] R. R. Varghese, P. Mathew Jacob, S. S, D. M. Ranjan, J. Cherian Varughese and H. Raju, "Detection and Grading of Multiple Fruits and Vegetables Using Machine Vision," 2021 8th International Conference on Smart Computing and Communications (ICSCC), 2021, pp. 85-89.