Automated Irrigation System using IOT & Ensemble Learning by fetching Real-time Data via Cloud.

'PROJECT WORK'

FINAL REPORT

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PROJECT COMPONENT

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DECLARATION BY THE CANDIDATE

We hereby declare that the J-Component report entitled "Automated Irrigation System using IOT & Ensemble Learning by fetching Real-time Data via Cloud" submitted by our Team to Vellore Institute of Technology, Vellore in partial fulfilment of the requirement for the award of the degree of Bachelor in Technology in Computer Science and Engineering is a record of bonafide J-Component undertaken by me under the supervision of our faculty Dr. SELVI M. We further declare that the work reported in this report has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

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BONAFIDE CERTIFICATE

This is to certify that the J-Component report entitled "**Automated Irrigation System using IOT & Ensemble Learning by fetching Real-time Data via Cloud"** submitted by **KOTHA V V S AAKASH (19BCE0186), EDULA VINAY KUMAR REDDY (19BCE0202),** and **PENUGONDA KOUSHIK (19BCE0117)** to Vellore Institute of Technology, Vellore in partial fulfilment of the requirement for the award of the degree of **Bachelor of Technology** in **Computer Science and Engineering** is a record of bonafide J-Component undertaken by them under my supervision. The training fulfils the requirements as per the regulations of this Institute and in my opinion, meets the necessary standards for submission. The contents of this report have not been submitted and will not be submitted either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

Signature of the Faculty

Keywords

- NodeMCU
- Automation
- Ensemble Learning
- DHT11

1. Abstract

The Internet of Things (IoT) refers to a system of interrelated, internet-connected objects that are able to collect and transfer data over a wireless network without human intervention. The Internet of Things (IoT) describes the network of physical objects—"things"—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. These devices range from ordinary household objects to sophisticated industrial tools.

In India, agriculture plays a major role in the country development in food production. In India most of people are doing work connected directly or indirectly to agriculture. Economy of India is mostly affected by activities related to agriculture. In our country, 60-70 percent agriculture depends on the monsoons which are not sufficient source of water. Water is one of the basic services to survive on earth is water. Also, Water is main resource for Agriculture. Irrigation is only method to supply water for Agriculture. In some cases, there will be lot of water wastage. There's challenge in front of every major country to reduce the water consumption used for farming and provide fresh and healthy food.

Internet of Things (IoT) is a milestone in the evolution of technology. IOT plays an important role in many fields, one of that is Agriculture by which it can feed billions of people on Earth in future. In this project, we are planning to make a Smart irrigation system that will Automate the Irrigation Process based on the current situation. These days the industries are using automatically controlled machines which are high in cost and not advisable for garden field. So, in this project we are planning to design an irrigation technology based on IoT using Arduino. Various Sensors will be used to check moisture of soil, temperature, Humidity, etc. This system can be used to control the water pump automatically. Data received by sensor will be sent to cloud for Decision Making. If the moisture level of the soil is less than the threshold, we initially set then it needs to be watered switching on the motor that will be attached with main controller. Before turning On the Motor or Water Pump, The Rainfall is Predicted by extracting the Real-time Data that is being stored in Cloud using the technique of Ensemble Learning in order to obtain an Optimal Result.

2. Introduction

The IoT can be described as an extension of the internet and other network connections to different sensors and devices — or "things" — affording even simple objects, such as lightbulbs, locks, and vents, a higher degree of computing and analytical capabilities. Interoperability is one of the key aspects of the IoT that contribute to its growing popularity. Connected or "smart" devices — as "things" in the IoT are often called — have the ability to gather and share data from their environments with other devices and networks. Through the analysis and processing of the data, devices can perform their functions with little or no need for human interaction.

Agriculture is the backbone of all developed countries. It uses 85% of available fresh water resources worldwide and this percentage continues to be dominant in water consumption because of population growth and increased food demand. India is one amongst the largest fresh users within the world, and our country uses great deal of H2O than any other country. There's an enormous quantity of water utilized in agriculture field instead of domestic and industrial sector. Sixty fifth of total water is contributes as a groundwater. Agriculture plays and important role in GDP of country. 60-70 percent of Indian population depend on agriculture for employment. IoT had help farmer to fight the most of problems is agriculture. India is the second largest country in the growth of population so it is necessary to increase the rate of production of agriculture. Every year irrigation requires more amount of water than the annual rainfall falls which has led to a critical phase of water resource for future generation. These days water has become one among the necessary supply on the world and most of utilized in the agriculture field. As our technology becomes progressively connected through the increase of IoT and Machine Learning, we've not solely benefited our lives however our planet similarly. The preservation of water resource for next generation and for proper water usage, it is necessary to adopt some of the strategies because of which minimal water is used as per requirement. There should be some of the techniques that can be implemented to stop wastage of water. IoT is the technology that enables us to adopt the strategies to monitor the usage of water via various Sensors. Hence, efficient water management is a major challenge in many arid and semi-arid farming systems. To optimize water consumption for agricultural crops, an automated irrigation system is required. The goal of an automated irrigation system is to avoid overwatering and under watering. Over irrigation happens as a result of inefficient waste water distribution or management, resulting in water pollution. In places with high evaporation, irrigation increases soil salinity, resulting in a deposit of harmful salts on the soil surface. To solve these issues and save manpower, a smart irrigation system was implemented. Soil moisture sensor is placed in the soil with crops because of which we come to know the moisture level of soil. Also, we place sensors to find temperature and humidity as well. All the Collected Data of moisture of soil, temperature, Humidity will be sent to Cloud in Real-time for Decision Making. If the Moisture of the soil is found to be less than a threshold set, then the Rain fall is predicted by Collected Data of temperature & Humidity using Ensemble Learning in order to Obtain an Optimal Result. The Water Pump is automated based on the Output of the Prediction mentioned above.

Agriculture is a major sector in India and some other southern African countries. With a rising population, there's a desire for increased agricultural production. In order to get greater production in farms, utilization of water will be more. Currently, agricultural land holds 84% of the water consumption in India. Unplanned usage of water in agricultural land means more water is getting wasted. This means that there should be quick development that will reduce the wastage of water. In today's society, automated irrigation systems have become a mandatory need in many places and continue to spread rapidly. From personal plant growing areas to large scale farms, people no longer have the time and material for manually watering their plants as required. Reducing the cost and increasing the efficiency of irrigation can be possible with remotely controlled automated irrigation systems having capability of making smart decisions. The Internet of things (IoT) makes remote and smart irrigation possible as it organizes agricultural things for the creation of necessary observation media. Over the past few years, farmers started using technology and software systems to prepare and keep their data about the crop and nowadays some state governments are also trying to make use of some apps by the farmers to get knowledge of various other crops. In the Internet period, the information plays an important role in people's daily usage, agriculture is rapidly increasing an awfully data intensive industry where farmers must collect samples and evaluate a large amount of knowledge from a variety of devices (e.g., sensors, farming machinery etc.). Using soil moisture sensors, it's easy to get the status of the moisture content in the soil near the plant based on the level of moisture we can irrigate the land whenever it is necessary. The proposed design makes use of ESP8266 and IoT which enables farmers to remotely monitor the status of the motor which makes their work easy. This project presents an intelligent irrigation system that predicts rainfall chances based on the information collected from the sensors deployed at the field and the weather forecast information available on the Internet. The server-side software has been developed with Python. Program has connectivity with ThingSpeak which gives us information visualization and decision support features. A novel algorithm has been developed for rainfall prediction, which is based on Ensemble Learning techniques applied on the sensor node data and the weather forecast data. The algorithm shows improved accuracy and less error. The proposed approach could help in making effective irrigation decisions with optimum water usage.

3. Literature Survey

[1] Title: IoT based low cost and intelligent module for smart irrigation system.

Challenges:

- Difficult to preserve important resources like water using available technologies.
- Not able to develop a low-cost intelligent system for smart irrigation.
- Challenging to create devices which can talk and connect on their own, with capabilities like user interaction, one-time setup for irrigation schedule estimation.

Methodology:

- **Step-1(Admin mode):** It starts with an admin mode for specific time duration in which the user needs to input data for the crop that is to be planted and for which IN schedule is desired, δ and soil type.
- **Step-2(One Time Setup):** After admin time-out, a one-time setup is done which loads the crop related data taken from user, which is then used to compute the evapotranspiration's and the irrigation needs.
- **Step-3(Continuous monitoring):** In the continuous monitoring module the phases involved are, (i) reading sensor data, (ii) connecting to MQTT broker and publishing data, (iii) mode decision, (iv) water decision, (v) decision transfer to IU, (vi) feedback from IU tasks are performed**.**

Applications:

Few applications regarding this research are Soil statistics management, Remote data monitoring, Neural network-based irrigation decisions, Alert systems on water wastage.

Pros:

- Low-cost proposal and its portability making it suitable for greenhouse, farms.
- Intelligent support and remote data monitoring of crops.

Cons:

- Should consider combination of evaporation types from soil surface and transpiration from the plant leaves, stems, flowers.
- Extra overhead due to continuous data sensing, data publish and decision making even in drizzly days.

[2] Title: Smart Irrigation system using Internet of Things.

Challenges:

- Issues related to utilization of available water in an efficient way are constantly obstructing the improvement of the nation.
- Challenging to identify the dampness in the soil and to control the watering of the crops automatically.

Methodology:

The data is first collected from the different sensors here Sensors like Moisture level of soil, Temperature of the area, air moisture and Water Level are used. They are attached to a breadboard which is intern connected to the Arduino Board. The data from the board is sent to the Arduino IDE. The programming language that is used runs instructions which extracts the data and reflects. If the data is not valid then the process ends.

Applications:

Few applications regarding this research are IOT building irrigation system using Node multipoint control unit, Rain alarm and soil moisture detectors.

Pros:

- Notification for users for necessary actions.
- Shrewd water system with brilliant control around right choice dependent on the continuous field information
- Ease to use system, even common people can know how to use these techniques to improve the productivity with adequate resources.

Cons:

- Data was not stored permanently for further use.
- Should consider cost effective prediction of soil moisture using the recorded data.
- System should be further customized for application categorical scenarios.
- System should minimize the cost by conducting a water saving analysis based on proposed algorithm with multiple nodes.

[3] Title: IoT-Based Smart Watering System Towards Improving the Efficiency of Agricultural Irrigation.

Challenges:

- Challenging to monitor the soil moisture of crops and the pH level of the irrigation water.
- Even though several smart watering systems have been proposed, none of the proposed systems consider both the pH of irrigation water and soil moisture together.

Methodology:

The (IBSWS) uses soil moisture sensors to accurately measure and compare the moisture of the soil to a threshold value to ensure that the soil is watered only when the plant needs it. Additionally, if the pH of the water being given to the soil is unsafe for the plant the IBSWS uses the Blynk platform on IoT to communicate to sub-level microcontrollers which use plant healthy acid and base pH solutions to modify the pH of the water being given to the plant. The system can be managed by the user via the IBSWS App created using Blynk, which allows the user to select the type of plant that they are watering so that the system can accurately manipulate the pH of the water given to the plant. The app can also be used by the user to monitor the pH and moisture levels monitored by the system.

Applications:

Few applications regarding this research are IOT based water conserving systems using sensors and microcontrollers, pH based Manual Restart and Safety systems.

Pros:

- Continuous monitoring of soil moisture and pH levels.
- Mobile app for farmers who use the system to monitor and control the irrigation system as well as the crop environment.

Cons:

- There may be effect of using IBSWS on plant health authors should monitor the true percent water savings that can be saved by using the IBSWS, while also tracking the plant health.
- System should be further customized for application by considering more features like season, land...

[4] Title: Advancing IoT-Based Smart Irrigation

Challenges:

Irrigation is a key issue to guarantee adequate crop yield by avoiding under- and over-watering. Water is an important cost driver, as the energy to transport water and to operate irrigation equipment is costly.

Methodology:

In this article authors used the concept of flexible IoT-machine learning (ML) , wherein IoT and ML components are connected as services in an application context, allowing adaptable solutions to fulfil application needs. It implements the flexible IoT-ML architecture toward the smart irrigation problem allowing highly customizable soil water management solutions, involving connectivity among data, physical models, and ML algorithms oriented to solve application key tasks, such as water need estimation and irrigation planning and operation.

Applications:

Few applications regarding this research are platforms for precision agriculture and experimentation in turmeric cultivation, Flexible Data-Driven Soil Water Management systems.

Pros:

- A flexible IoT-machine learning (ML) platform are connected as services in an application context, allowing adaptable solutions to fulfill farmer's needs.
- Huge benefits for IoT professionals, as they can easily develop and deploy complex solutions involving devices, communication, data management, analytics, and application elements.

Cons:

- System may produce invalid results due to quantitative impact data authors should analyze the data and disseminate quantitative impact results.

[5] Title: An efficient mechanism using IoT and wireless communication for smart farming

Challenges:

- Challenging to bring new quantitative approaches in light of new internet-of-things (IoT) technologies to fulfill food resources need of the country.
- To aggregate data regarding their agriculture field in real time using IOT sensors.

Methodology:

In this article authors proposed a WSN framework based on the Internet of Things for use in smart agriculture, with different design levels to choose from. The first step is having sensors on the farm which are capable of collecting relevant data and determining the appropriate cluster heads. In addition, the signal strength on the communication link is calculated by means of the signal to noise ratio (SNR) in order to attain reliable and competent information diffusion over long distances. Second, the recurrence of the linear congruential generator is used to ensure the security of information spread as of agricultural sensors to base stations (BS) by means of the linear congruential producer

Applications:

Few applications regarding this research are Energy and link efficient routings, Secure data transmission systems from agriculture sensors.

Pros:

- Proposed system significantly improved communicate routine by standard of 16.3 percent in system throughput, 36.3 percent in packet drop ratio, 12.4 percent in network latency, 18 percent in energy consumption, and 19 percent in routing overheads compared to other IOT existing systems.

Cons:

- When it comes to data transmission, the proposed framework uses a single-hop paradigm,

Which may cause single point failure between agriculture sensors and base stations.

[6] Title: A smart agriculture IoT system based on deep reinforcement learning.

Challenges:

- Increasing food production and reduce the consumption of resources like fresh water.
- Challenging to use deep reinforcement learning in smart agriculture.

Methodology:

In this article authors proposed a smart agriculture IoT system based on deep reinforcement learning which includes four layers, namely agricultural data collection layer, edge computing layer, agricultural data transmission layer, and cloud computing layer. The system integrates some advanced information techniques, especially artificial intelligence and cloud computing, with agricultural production to increase food production. The most advanced artificial intelligence model, deep reinforcement learning is combined in the cloud layer to make immediate smart decisions such as determining the amount of water needed to be irrigated for improving crop growth environment.

Applications:

Few applications regarding this research are Applied deep reinforcement learning for energy management, high dimensional robot control using deep learning.

Pros:

- Instead of human involvement deep reinforcement learning models are used to make smart decisions to adjust the environment to adapt to the growth which decreases the manual human errors.
- Advanced information techniques like artificial intelligence and cloud computing are used to increase agricultural food production.

Cons:

- Although deep reinforcement learning has shown a great progress in model design and training algorithms, it cannot achieve the human-level performance in adaptation to dynamic environments and solving complex tasks.
- Authors should design the incremental models to speed up the training for deep reinforcement learning in dynamic environments for smart agriculture systems
- Cloud computing should be used to improve the training efficiency of large-scale deep reinforcement learning for complex tasks

[7] Title: Towards Precision Agriculture: IoT-Enabled Intelligent Irrigation Systems Using Deep Learning Neural Network

Challenges:

- The main challenge is, Due to the ever-growing world population demands for food and water. Consequently, farmers will need water and arable land to meet this demand. Due to the limited availability of both resources, farmers need a solution that changes the way they operate.
- Another challenge is even though there are Several machine learning-based irrigation models have been proposed to use water more efficiently. Due to the limited learning ability of these models, they are not well suited to unpredictable climates.

Methodology:

The proposed irrigation model consists of four main components to support the end user's decision to irrigate the farmland with a suitable amount of water. The first component includes a set of nodes (e.g., soil sensors, environmental sensor-actuator nodes, rain-gauge sensors). Actuator nodes have wired connections with water valves/sprinkles to control the sprinkle flow rate. The second component includes anchor nodes and servers. Anchor nodes forward received data from sensors to the radio gateway, which further forwards these data to a server for storage. The third component includes a deep LSTM RNN model to predict the volumetric soil moisture content for the next day based on the previous day's climate and soil information. The output of the third component is sent to the authorized end-user interface (e.g., smartphone with irrigation application), which is part of the fourth component.

Applications:

Few applications regarding this research are data analytical applications that augment complicated agricultural issues, irrigation with smartphone models, learning-based irrigation models.

Pros:

- The proposed model shows high water saving compared to the FANNN and T-based models by maintaining the soil moisture deficit within the allowed range.
- Proposed model uses water more wisely than state-of-the-art models in the experimental farming area.

Cons:

- Sometimes model may not work properly as the authors only considered the soil moisture content. More water can be saved through maximum utilization of rainfall depths in addition to soil moisture.

[8] Title: Application of IoT and Cloud Computing in Automation of Agriculture Irrigation.

Challenges:

- Challenging to make agricultural irrigation more efficient without actually knowing which day requires how much amount of data.
- A system like smart irrigation system can be very precise, but the issue is it needs information about the soil and the weather in the area where it is going to be used.

Methodology:

In this article authors used cloud based IOT approach. All soil related data is stored in centralized cloud storage. Climate data of that region is also stored in cloud. This cloud has machine learning algorithms like SVM, random forest, and Naive Bayes. Machine learning algorithms are applied on soil data and climate data to obtain the correct quantity of data required by a particular crop and then this information is made available to registered user by mobile applications. Registered user can view predictions of machine learning. Registered user can set humidity and moisture level for his crop. A "Raspberry Pi" board is utilized as a keyboard and mouse through USB ports. For a display, authors utilized the "Raspberry Pi" board as the HDMI port. Ethernet port is used to connect the machine to the Internet through LAN.

Applications:

Few applications regarding this research are crop yield prediction, crop quality managements, weed detection in crops, livestock management using ML based approaches.

Pros:

- Using this machine learning approach farmers can anticipate the proper amount of fresh water required for a crop to be cultivated. As a result, a significant amount of fresh water is saved.
- Effective results can be expected in normal conditions as the model is considering soil data from that region, as well as climatic data from that region.

Cons:

- As only 330 records are considered in dataset, in unexpected climate days on which the model is not trained then the model can predict false results which may leads to water wastage or water storage.

[9] Title: Internet of Things (IoT) for Smart Precision Agriculture and Farming in Rural Areas.

Challenges:

- Challenging to reduce network latency in IoT-based agriculture and farming solutions.
- Challenging to connect the agriculture and farming bases situated in rural areas efficiently with the use of fog computing and Wi-Fi-based long-distance network with less latency.

Methodology:

In this article authors proposed a network solution in the domain of IoT connecting the rural region with various agricultural and farming applications using Wild network and fog computing in the existing WSN-based solutions for covering longer range with lesser delay then a cross-layer-based MAC and routing solution is used which adapts traffic nature and sets the duty cycle accordingly to improve delay and throughput performances over multi hop. Then the network is analysed based on coverage range, throughput, and latency.

Applications:

Few applications regarding this research are soil and Scientific disease and pest monitoring, water quality monitoring, farm monitoring, cattle movement monitoring, Remote control and diagnosis.

Pros:

- Compared to the existing IoT-based agriculture and farming solutions, the proposed solution reduces network latency up to a certain extent.
- The MAC and routing solution used for IoT have achieved better energy, delay, and throughput performance.

Cons:

- As the security of long distance covering wireless network is not considered there may be chance of attacks like tampering and manipulation of data.

[10] Title: IoT-Agro: A smart farming system to Colombian coffee farms.

Challenges:

- One of the main issues is even though there are several scientists consider Smart Farming as the best solution. However, they fall short in providing more information to recommend the most appropriate IoT technology.
- It became challenging to the farmers in selecting the most appropriate technologies from a wide range of options.

Methodology:

In this article authors proposed a Smart Farming System based on a three-layered architecture (Agriculture Perception, Edge Computing, and Data Analytics). In the Agriculture Perception Layer, authors evaluated Omicron, Libelium, and Intel technologies under criteria such as the price, the number of inputs for sensor connection, communication protocols, portability, battery life, and harvesting energy system photovoltaic panel then in edge-based management mechanisms in the Edge Layer to provide data reliability, focusing on outlier detection and treatment using Machine Learning and Interpolation algorithms. In the Data Analytics Layer, authors evaluated different machine learning algorithms to estimate coffee production.

Applications:

Few applications regarding this research are Plants and crops disease detection, Ground water level prediction using data analytics, Smart farming system in coffee farms.

Pros:

- Farmers can monitor environmental variables of the coffee zone by plots, farm, or region.
- Farmers can make their own crop management decisions in coffee trees based on their real data
- Farmers plan the activities before the harvest based on coffee production estimation per year avoiding money loss in production.

Cons:

- This system can be improved by implementing IoT-Agro services in more stages of the coffee value chain, such as storage, transport, and exportation.

[11] Title: An IoT Based Smart Irrigation System

Challenges:

In previous technology it doesn't have a real-time monitoring system, remote controlling and cloud computation of acquired data. We have to manually turn on and turn off the switch. We can't measure soil moisture level, pH level, nutrient content of the soil.

Methodology:

This paper mainly revolts around the automation aspect of the project as much as it can be controlled manually. In this paper Three different types of sensors have been implemented for measuring three different parameters simultaneously. The data is then sent to the system hub which consists of Arduino and NodeMCU. A display is also installed for viewing the output figures at the spot. NodeMCU transports the data to the digital platform of the server for processing of the data. Then those data are sent to the mobile application of the user. The user then can perform manual tasks or can choose not to as Arduino will be executing the required commands if the parameter levels fall below the threshold values. Another motor of the system is used for pesticide. After a certain amount of time or at a specific time interval this motor is switched on to provide the legitimate volume of substance then switch off by itself.

Applications:

- This can be used by lot of farmers as this helps them to easily monitor their fields.
- The real time data that we get can be used for further research to build an effective model.

Pros and cons:

Pros:

- We can easily find out all the readings like pH level, soil moisture, temperature.
- It automatically turns on and turns off the motor.
- We can see real time data through cloud and asses the condition of our farm.

Cons:

- The pricing that came within the components were a bit overpriced.
- It can't find out the health of crops which can be done using image processing.
- It takes some time to get real time data to the mobile application.

[12] DESIGN AND OPTIMIZATION OF LOT BASED SMART IRRIGATION SYSTEM IN SRI LANKA

Challenges:

In previous technology it doesn't have weather based smart irrigation system. In previous technology it only has real time data but here it can store all the data like soil moisture content, temperature, humidity, rainfall and other parameters in remote server and can be used for further processing such as in weather prediction, soil condition analysis, disease analysis.

Methodology:

First of all, an efficient drip irrigation system which can automatically control the water supply to plants based on soil moisture conditions is developed. Next, this water efficient irrigation system is given loT-based communication capabilities to remotely monitor soil moisture conditions and to manually control water supply by a remote user. Further, temperature, humidity and rain drop sensors are integrated to the system and is upgraded to provide monitoring of these parameters by the remote user via internet. These weather parameters of the field are saved in real time in a remote database. Finally, a weather prediction algorithm is implemented to control the water supply according to the existing weather condition. The proposed smart irrigation system will provide an effective method to irrigate farmer's cultivation.

Applications:

- This can be used in Investigating weather forecasting model to build an effective model.
- This can be used to Predicted rainfall value by using the algorithm.

Pros and cons:

Pros:

- One major advantage is to automate watering crops to optimize water consumption and increase productivity.
- Lack of water as well as over supply of water could lead to water stress of plants and also reduce the growth rate of plants but this can easily overcome that.
- It monitors level of water evaporation and supplying water to maintain the soil moisture level at a proper level would enhance the productivity of plants.
- Drip irrigation roughly requires only half of the water requirement that of the sprinkler or surface irrigation. In addition, lower operating water pressures and flow rates also reduce the energy costs.

Cons:

- It doesn't enhance Sliding Window algorithm to predict the rainfall amount by adding extra features like density of clouds by taking cloud images, satellite images.
- It doesn't make LPU system to work with low power and also to power the system via solar power to be implemented the system in areas with difficulty accessing grid power.

[13] PV BASED ISOLATED IRRIGATION SYSTEM WITH ITS SMART IOT CONTROL IN REMOTE INDIAN AREA

Challenges:

It's completely different from existing technologies. This paper presents a techno-economic analysis of a PV based irrigation system which can remotely be installed for an eastern coastal area in India. Due to the automated system considered, the use of water for irrigation will be optimal and system will also require minimal maintenance.

Methodology:

The pumped irrigation will be automatically controlled based on the availability of the PV generated power and the system load. The pump load is dependent on the soil moisture content. For the system automated control at first, the PV module power is read by the controller. Also, the moisture content is checked continuously whether it is greater or less than threshold valueUTh . The project contains two distinct studies; one is HOMER simulation suggesting techno-economic validation. Next is the hardware prototype IoT based control. For the laboratory experimental setup, only the system ratings, moisture information, PV panel power and battery SoC are needed. The system is simulated for a period of 20 years. The soil moisture content can also be remotely monitored via an Internet of Things (IoT) based controller. The IoT is enabled using ESP8266 controller board with the laboratory circuitry From the data obtained, the requirement of the PV panel to supply loads i.e. watering of the soil or to store the surplus energy content in storage batteries can be determined. Thus, the IoT based monitoring plays a major role in determining the control strategy for the proposed plant.

Applications:

This can be mainly used in Remote Indian Area to develop a PV based Isolated Irrigation System.

Pros and cons:

Pros:

- In this they have taken the parameters such as irradiation, moisture content of soil, availability of load, etc. has been extensively taken into account which can be useful to get better results.
- The irrigation system also has a storage battery for storing and retrieving the energy available for the PV module and for supplying loads.

CONS:

- Control techniques used are too complex to implement also the economic analysis for setting up of such a system in practical conditions are not studied.
- Initial and running cost of such a system can be on the higher side due to the use of PV modules and storage batteries.

[14] FUZZY LOGIC BASED SMART IRRIGATION SYSTEM USING INTERNET OF THINGS

Challenges:

There are many disadvantages of the existing traditional agricultural methods namely costlier and manual monitoring of the agriculture field. Specifically, small-scale smart irrigation systems are utilized to provide the solution for dissimilar variety of plants in spite of getting the solution for moisture related issues. But this paper provides solutions for all these in an effective way.

Methodology:

The smart agriculture irrigation controlling and plant disease monitoring system has four major units: end device node, coordinator node, web server node and mobile (controlling unit). The end device node consists of Arduino controller, GSM, motor, plant leaf image soil moisture sensor, temperature sensor and humidity sensor. The microcontroller device is used as the end device as well as the coordinator device in the wireless sensor network. It is used for data communication in the network. The proposed fuzzy-based smart irrigation system provides acknowledgement message about the job's statuses such as humidity level of soil, temperature of surrounding environment periodically. Based on the soil moisture sensor output, the motor is turned on or off automatically to prevent excessive usage of water and electricity. Based on the availability of rain, the motor is turned off automatically to save power. Usage of solar panel reduces the power consumption drastically. The soil moisture sensor checks for the soil moisture content whose maximum threshold is kept at 850 (indicating dry) and minimum of 500. When the soil moisture content is greater than 700, the motor will pump water to the agricultural filed. All the information gathered from sensors will be transferred to the user using GSM technology

Applications:

Agricultural fields of farmers may be located miles away from their residence. Sometimes, farmers need to travel to their agricultural field for quite a few times in a day to start and stop water pumps for irrigation. They cannot guard the crops from unconditional rain every time. So it can be very helpful for farmers who live far from their fields.

Pros and cons:

Pros:

- This system provides acknowledgement messages about the job's statuses such as humidity level of soil, temperature of surrounding environment, and status of motor regarding main power supply or solar power.
- The system also switches off the motor to save the power when there is an availability of rain and also prevents the crop using panels from unconditional rain

Cons:

- The primary disadvantage associated with this system is that this is expensive which most of the farmers cannot afford.
- Accuracy is also a major defect in these systems.

[15] ADAPTING WEATHER CONDITIONS BASED IOT ENABLED SMART IRRIGATION TECHNIQUE IN PRECISION AGRICULTURE MECHANISMS

Challenges:

In this paper they proposed a holistic smart agriculture application that consists of various agricultural sensors, drones, and IoT hardware and software utilities. Several sensors are able to gather specific cornfield data and send it to the coordinator node which is capable of communicating with a drone. The drone flies over the large-scale cornfields at certain times of the day and collects the data from coordinator nodes. It delivers the cornfield data to the gateway as a relay node. The farmers monitor the data on graphical monitoring interfaces with the help of IoT software

Methodology:

The system uses heterogeneous sensor nodes which are capable of sensing acoustic, rain, wind, light, temperature and pH levels of the cornfields for smart agriculture applications. The specific properties of the cornfields are gathered with special purpose sensors at coordinator nodes, and then the coordinator node sends the data to the Drone as a relay node. It is sufficient for the sensor nodes to detect conditions at specific times of the day because the data in the cornfields does not change rapidly. The Drone provides data to the base stations for monitoring on farmers' visual devices. Therefore, the necessity of long-distance communication between sensors in a region of large-scale cornfields is eliminated.

Applications:

- Large-scale cornfields can be monitored with different sensors for irrigation, insect and pest detection, crop status, fertilization, soil preparations, etc.
- Various IoT capabilities are used for smart agriculture activities.
- Ten different specifications about cornfields are monitored on Grafana.

Pros and cons:

Pros:

- In this Drone assisted data gathering process is also developed for large-scale cornfields.
- CSMA/CA-based wireless network is proposed for each acre of cornfield.

Cons:

- This paper only discusses about corn fields. It fails to work for other crops.

[16] IOT BASED SMART AGROTECH SYSTEM FOR VERIFICATION OF URBAN FARMING PARAMETERS

Challenges:

Agricultural fields of farmers may be located miles away from their residence. Sometimes, farmers need to travel to their agricultural field for quite a few times in a day to start and stop water pumps for irrigation. They cannot guard the crops from unconditional rain every time. In order to remove these practical difficulties, a system is designed to take care of all these problems automatically.

Methodology:

It can be explained in a few steps like data collection of soil using sensors, data processing using microcontrollers, web interfacing, etc. Humidity and temperature sensors and soil moisture sensors are integrated into the proposed system, where data are collected from the site and send to the microcontroller to analyse the data. This scheme introduces ESP8266, an IoT based tool that connects all the sensors and acts as a controller of the system. ESP8266 provides output voltage not more than 3.3 V, but the soil moisture sensor and DHT11 sensor require a 5 V supply. Thus, an external 5 V dc power supply is provided to supply the power to these sensors. The external dc power supply receives 220 V ac supply, and after rectification and filtering, it addresses a voltage regulator and then converts to the required dc supply. The relay module can be operated at 3.3 V that is supplied from the ESP8266 and can control switching to operate a water pump based on the command from the controller. The controller is programmed through Arduino IDE, where the DHT11 library is introduced as an external library.

HI = C1 + C2T + C3R + C4TR + C5T2 + C6R2 + C7T2R + C8TR2 + C9T2R2

Where HI is the heat index in degrees Fahrenheit, R is the relative humidity, and T is the temperature in degree Fahrenheit.

Applications:

- This can be used in urban areas, especially building roofs, open gardens, and indoor agriculture.
- This can be even used in rural areas to water the farms very accurately.

Pros and cons:

Pros:

- The proposed system decides whether the irrigation action should begin or stop depending on the farming land condition and provides the monitoring facility and remote control to the farm owner.
- Comparative analysis between actual data and observed data of humidity, temperature, and soil moisture provide an average percentage of error is only 2.93%, 1.12%, and 2.51%, respectively.

Cons:

- All this is very expensive and it has complex structure that farmers can't understand.

[17] AGRISENS: IOT-BASED DYNAMIC IRRIGATION SCHEDULING SYSTEM FOR WATER MANAGEMENT OF IRRIGATED CROPS

Challenges:

Water management of irrigated crops is one of the key parameters governing precision agriculture. Low irrigation in terms of water management and scheduling causes crop stress and ultimately reduces crop yield. Hence, there is a great demand for efficient irrigation that necessitates the availability of precise information about irrigation demand in near real time.

Existing works focus on either automatic or manual irrigation. However, the idea of proposing a complete system providing automatic dynamic as well as remote manual irrigation treatment in the different growing stages of a crop is still far fetched. This motivates our AgriSens work.

Methodology:

They designed a real-time automated irrigation system for crop fields using IoT and propose an algorithm for automatic dynamic irrigation treatments in the different phases of a crop's life cycle. In addition to automatic irrigation, the proposed AgriSens system offers manual irrigation, remotely, which is based on the farmer experience or expert inputs. Design a low-cost water-level sensor that generates discrete values according to the level of water present in a field. AgriSens provides field information to the farmers in different ways, such as visual display, cell phone, and Web portal using general packet radio service (GPRS)- enabled light-emitting diode (LED) array and liquid crystal display (LCD), global system for mobile communication (GSM) technology, and the Internet.

Applications:

- This can be used in Evaluation of Climatic Condition.
- This can be used in Dynamic Irrigation Treatment.
- The cost of each sensor node is approximately $20 and that of the water-level sensor is approximately $4, which shows low cost due to the requirement of the simplest circuits. Hence, the cost of AgriSens is effectively low.'

Pros and cons:

Pros:

- Soil Moisture Data Accuracy.
- The Packet delivery ratio (PDR) of the AgriSens always lies between 95.53% and 97.42% due to the higher value of received signal strength indicator, and hence maintains consistency in respect of successful packets transmission to the destination.

Cons:

- The PDR of the SM system is highly varying between 70.98% and 93.66%.

[18] INTERNET-OF-THINGS (IOT)-BASED SMART AGRICULTURE: TOWARD MAKING THE FIELDS TALK

Challenges:

Expectations of the world from the agriculture industry. Very recent developments in IoT, both scholarly and in industry are highlighted and how these developments are helping to provide solutions to the agriculture industry. Limitations, the agriculture industry is facing. Role of IoT to cope these limitations and other issues like resources shortage and their precise use, food spoilage, climate changes, environmental pollution, and urbanization. Strategies and policies that need to be considered when implementing IoT-based technologies. Critical issues that are left to solve and possible solutions that are further required, while suggestions are provided considering these challenges.

Methodology:

The focus on smarter, better, and more efficient crop growing methodologies is required in order to meet the growing food demand of the increasing world population in the face of the ever-shrinking arable land. The development of new methods of improving crop yield and handling, one can readily see currently: technology-weaned, innovative younger people adopting farming as a profession, agriculture as a means for independence from fossil fuels, tracking the crop growth, safety and nutrition labeling, partnerships between growers, suppliers, and retailers and buyers. This project considered all these aspects and highlighted the role of various technologies, especially IoT, in order to make the agriculture smarter and more efficient to meet future expectations. For this purpose, wireless sensors, UAVs, Cloud-computing, communication technologies are discussed thoroughly. Furthermore, a deeper insight on recent research efforts is provided. In addition, various IoT-based architectures and platforms are provided with respect to agriculture applications. A summary of current challenges facing the industry and future expectations are listed to provide guidance to researchers and engineers.

Applications:

- Water and nutrition monitoring
- Diseases and bug monitoring
- Soil monitering
- Fertilizer management
- Spraying Applications

Pros and cons:

Pros:

- 70% of farming time is spent monitoring and understanding the crop states instead of doing actual field work.

Cons:

- Accuracy is also a major defect in these systems.

[19] ZONING IRRIGATION SMART SYSTEM BASED ON FUZZY CONTROL TECHNOLOGY AND IOT FOR WATER AND ENERGY SAVING

Challenges:

Water plays an important role in the agricultural development process because it is an essential element for plant growth. Therefore, the necessary and sufficient quantity of water should be provided at the adequate time to improve and increase the agricultural production. In addition, because of the climate change, authorities are worried about water availability in many countries where the overall demand for water has considerably and rapidly increased. Traditional irrigation strategies are not satisfactory to deal with water shortages. In fact, the land and water resources are enough to produce food over the next fifty years, but only if water is well managed for agriculture. To increase water control and thus reduce water use, this sector must benefit from modern technological advancements and new solutions must be explored.

Methodology:

The proposed system based on a Wireless Sensors Network (WSN) was installed in different considered zones of a greenhouse. This network sends the data from the plant environment, such as soil humidity and temperature to a server (Raspberry pi) by means of radio-frequency (RF) communication. To control the irrigation, a fuzzy logic controller (FLC) processes these data and makes an intelligent and optimal decision. The developed system can monitor and control the irrigation in the greenhouse from anywhere and at any time by using a Human Man Interface (HMI) developed under Node-RED of IBM. The proposed system was applied to irrigate tomato plants in a real environment. Comparison of the irrigation performance with three other irrigation techniques shows that the amount of water and the consumption of energy by adopting the proposed method decreased significantly.

Applications:

- Optimization of plant growing conditions and the reduction of water use and energy consumption.

Pros and cons:

Pros:

The evaluation of soil moisture corresponding to the two zones with the FLC under different temperatures of the environment during one week. These findings, as expected, show that the FLC controlled effectively the soil moisture, which had been successfully stabilized between 400% and 500%, which corresponds to the ideal condition for the considered plant.

Cons:

Although we are convinced that the proposed system is efficient and provides an improvement on water and energy saving compared to the other existing irrigation strategies, it is very difficult to give an exact percentage improvement in this manuscript because it needs a comparison on several scales and each scheme has its advantages and limitations.

[20] MOBILE INTEGRATED SMART IRRIGATION MANAGEMENT AND MONITORING SYSTEM USING IOT

Challenges:

Agriculture has been the most important practice from very beginning of the human civilization. Traditional methods that are used for irrigation, such as overhead sprinkler and flood type, is not that much efficient. They result in a lot of wastage of water and can also promote disease such as fungus formation due to over moisture in the soil. Automated irrigation system is essential for conservation of the water and indirectly viability of the farm since it is an important commodity. About 85% of total available water resources across the world are solely used for the irrigation purpose. In upcoming years this demand is likely to increase because of increasing population. To meet this demand we must adopt new techniques which will conserve need of water for irrigation process.

Methodology:

They have used an android application i.e. Blue term. These applications work totally on Bluetooth. To interface the android application and the master robot we require a Bluetooth module. The application blue term is used for coding and writing programming instructions and this programming data is sent via Bluetooth to the paired Bluetooth module. This application acts like an emulator which then is given as the input to the microcontroller Raspberry pi. This Set of codes is then given to the input of the motor driver which is responsible for the movement of the motor. As a result of which the Motor will start and water will be supplied to plants. The same codes are simultaneously sent to the output pin of the microcontroller

Applications:

- To control the water supply and monitor the plants through a Smartphone.

Pros and cons:

Pros:

- The system features a custom sensor design for power efficiency, cost effectiveness, cheap components, as well as scalability end ease of use.

Cons:

- The system should be further extended for outdoor utilization.

4. Existing Methods

In General, there is no Automated method Existing for Irrigation that is being deployed everywhere. But there are some of the researches done in this field of automating the process of irrigation. The basic method deployed for Automated Irrigation in most of the Existing Researches is: Firstly, the data is first collected from the different sensors to find out Moisture level of soil, Temperature of the area. They are attached to a breadboard which is intern connected to the Arduino Board. The data from the board is sent to the Arduino IDE. The programming language that is used runs instructions which extracts the data and reflects i.e., Based on the extracted information, a Decision is made where to turn the water pump "On" or not based the Thresholds we initially set. If the data is not valid then the process ends.

5. Hardware and Software Details

5.1. Hardware used:

1) NodeMcu ESP8266
2) Soil Moisture Sensor Module
3) Submersible DC motor
4) DTH11 sensor
5) Relay module

NodeMcu ESP8266: It is an open-source device for IoT. It is a 32-bit microcontroller which allows connected objects to transfer data from Wi-Fi. It is a low-cost chip which has built in TCP/IP networking software's. It has 17 GPIO pins. It has Tensilica L 106 RISC processor which has low power consumption. It is integrated with power amplifiers, ADC's and some power management modules. It has storage of 4KB of memory. Fig 1 shows the typical NodeMcu

Fig 1: NodeMcu

Soil Moisture Sensor Module: Soil moisture sensor is to measure the content of water in the soil. It mainly consists of a pair of conducting probes. It measures the moisture based on the change in resistance between those probes. resistance is inversely proportional to the amount of moisture present in the soil.it sends analog data after passing this into ADC the value will range from 0 to 1023.so if there is no water in the soil the value will be 1023.So for changing this value into percent we need map (0,1023) to (1,100) which can be done using map function. Fig 2 shows the Soil Moisture Sensor.

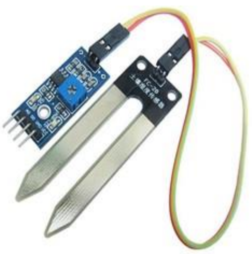


Fig 2: Soil Moisture Sensor Module

Submersible DC motor: It is a kind of motor which will be fully submerged in water. The motor is hermetically sealed in order to avoid flow of water into the motor. It pushes water to the surface by converting rotational energy into kinetic energy into pressure energy. This motor will be placed in the water and we will connect a pipe to it for the outcome of the water.

Fig 3: Submersible pump

DTH11 sensor: It is a general-purpose sensor used for measuring temperature and humidity in the atmosphere. It consists of humidity sensing material and thermistor for sensing the temperature. a humidity sensing material is a capacitor which has Humidity as a dielectric substance between them, change in the Humidity leads to the change in the capacitance. We know how thermistors work. According to the temperature the value of resistance changes. It has an operating voltage of 3-5v which we can get from the NodeMcu.

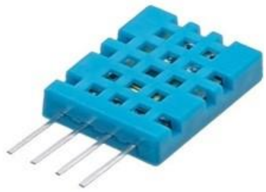


Fig 4: DTH11 Sensor

Relay Module: It is an Electrical switch that operates on the application of magnetism. The main purpose of the Relay module is to run the motor. Maximum voltage produced by the NodeMcu is 5v which is not enough to run the motor. So, in order to run the motor, we will connect the relay module to the NodeMcu and for powering the module we use a 9v battery. whenever we want to turn ON the motor we will send a high to low pulse to the relay module then the switch will close then 9v will go to the motor. Fig 5 shows the typical example of the single channel Relay module.

Fig 5: Relay Module

5.2. Software used:

1) Arduino IDE
2) ThingSpeak

Arduino IDE: It is very useful for writing the code and compelling the code for NodeMcu. It is generally created for Arduino boards but we can use it to write, compile and upload sketches of NodeMcu by using third party cores. program written in this IDE (Integrated Development Environment) called Sketches. Generally, these sketches will be written in text editor and will be saved as .ino files. Arduino IDE is a cross-platform application which means we are able to run this on different operating systems on Windows, Linux, MacOS and other different platforms. This has the advantage of seeing a serial monitor window in which we can see the output of different data provided from the sensors.

ThingSpeak: ThingSpeak is an IoT platform which is useful for visualization of the data which is posted by your device to the Thing speak. which we can perform some analytics on the posted data using MATLAB. We can send the data to the ThingSpeak using Rest API or MQTT by using API keys provided during the creation of the channel. ThingSpeak under MathWorks. That's we can analyse our data using MATLAB.

6. Proposed Methodology

Step1: Irrigation can be automated by using sensors, microcontroller, Wifi module, ThingSpeak platform as shown in Fig.1.For maintaining all the sensors and to drive the motor whenever required we need a controller. For this purpose, we have used NodeMcu. The Maximum voltage we can get from the NodeMcu is 5v. 5v is enough to drive the moisture sensors module and DTH11 sensor but it is not enough to drive the motor. In order to run a motor, we need at least 7v. To overcome this problem, we have used a 9v battery to drive the motor. In order to control the motor whenever required we need a switch. For this purpose, we have used a relay module. It is an Electrical switch. If we want to close the switch then we need to send a high pulse to the module. The soil moisture sensor continuously monitors the field. The sensors are connected to Node MCU. The sensor data obtained are transmitted through wireless transmission and are reached to the user so that he can control irrigation.

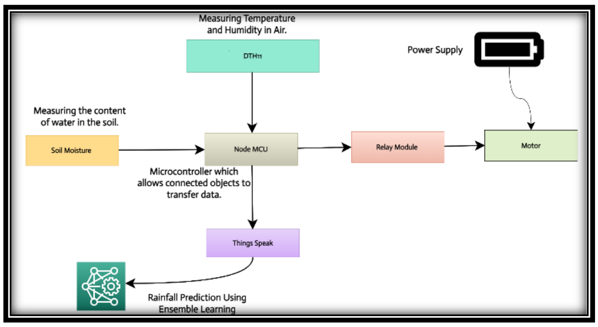
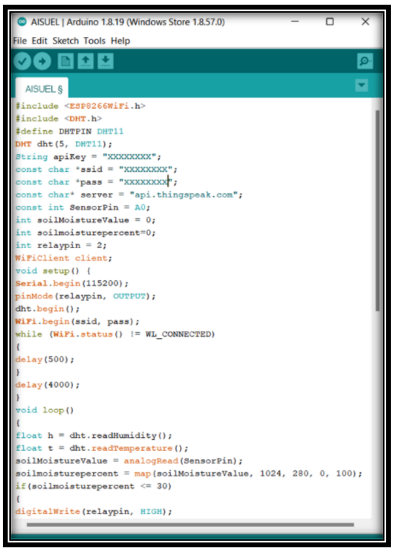


Fig 6: System Architecture

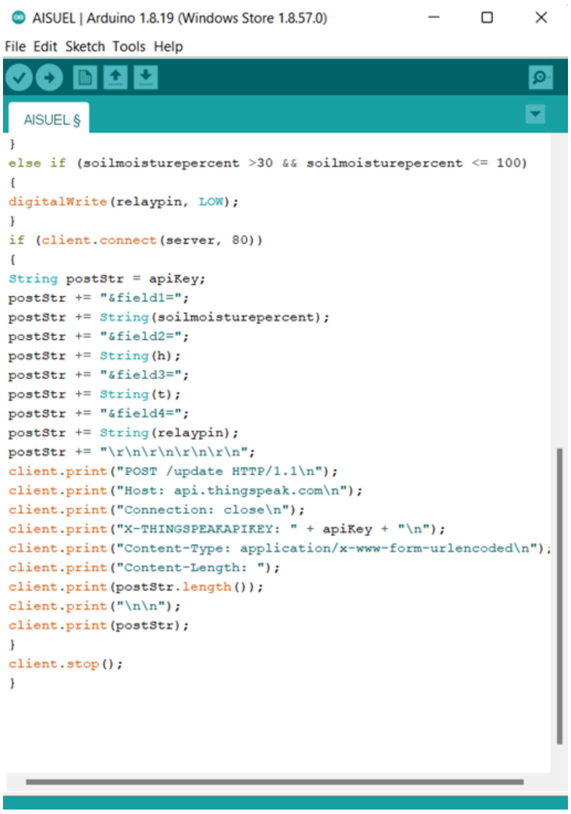
Step2: Finally, all the data needs to be there in ThingSpeak for visualisation. by using write API keys we will send the sensor data to the server. In ThingSpeak we can visualise the data of every sensor over the time.

Implementation:



```
#include <ESP8266WiFi.h>
#include <DHT.h>
#define DHTPIN DHT11
DHT dht(5, DHT11);
String apiKey = "XXXXXXXX";
const char *ssid = "XXXXXXXX";
const char *pass = "XXXXXXXX";
const char* server = "api.thingspeak.com";
const int SensorPin = A0;
int soilMoistureValue = 0;
int soilmoisturepercent=0;
int relaypin = 2;
WiFiClient client;
void setup() {
Serial.begin(115200);
pinMode(relaypin, OUTPUT);
dht.begin();
WiFi.begin(ssid, pass);
while (WiFi.status() != WL_CONNECTED)
{
delay(500);
}
delay(4000);
}
void loop()
{
float h = dht.readHumidity();
float t = dht.readTemperature();
soilMoistureValue = analogRead(SensorPin);
soilmoisturepercent = map(soilMoistureValue, 1024, 280, 0, 100);
if(soilmoisturepercent <= 30)
{
digitalWrite(relaypin, HIGH);
```

Fig 7: Arduino Code for sending the sensor data to ThingSpeak.




```
}
else if (soilmoisturepercent >30 && soilmoisturepercent <= 100)
{
digitalWrite(relaypin, LOW);
}
if (client.connect(server, 80))
{
String postStr = apiKey;
postStr += "&field1=";
postStr += String(soilmoisturepercent);
postStr += "&field2=";
postStr += String(h);
postStr += "&field3=";
postStr += String(t);
postStr += "&field4=";
postStr += String(relaypin);
postStr += "\r\n\r\n\r\n\r\n";
client.print("POST /update HTTP/1.1\n");
client.print("Host: api.thingspeak.com\n");
client.print("Connection: close\n");
client.print("X-THINGSPEAKAPIKEY: " + apiKey + "\n");
client.print("Content-Type: application/x-www-form-urlencoded\n");
client.print("Content-Length: ");
client.print(postStr.length());
client.print("\n\n");
client.print(postStr);
}
client.stop();
}
```

Fig 8: Arduino Code Cont.

Step3: Fetching the data from ThingSpeak to our python script

1. Import all required libraries (json, urllib.request).
2. Create an API using READ_API_KEY and CHANNEL_ID of ThingSpeak.
3. Request the ThingSpeak website by using urllib.request module.
4. Store the json response from ThingSpeak.
5. Retrieve temperature, Humidity, Soil moisture values from json data.

```
import json
import urllib.request
READ_API_KEY='9FU2ND2YUH8QBV81'
CHANNEL_ID= '1696440'
while True:
    ThingSpeak = urllib.request.urlopen("http://api.thingspeak.com/channels/%s/feeds/last.json?api_key=%s" \
% (CHANNEL_ID,READ_API_KEY))
    response = ThingSpeak.read()
    data=json.loads(response)
    curr_time = data['created_at']
    Temperature= data['field1']
    Humidity = data['field2']
    SoilMoisture = data['field3']
    print("\nCurrent Time is: " +curr_time+ "\nTemperature is: " +Temperature + "\nHumidity is: " + Humidity + "\nSoil
Moisture is: " + SoilMoisture)
    time.sleep(5)
    ThingSpeak.close()
```

Step4: Rainfall prediction using Ensemble Learning

1. The weather dataset is taken from Kaggle platform.
2. Numerous learning methods are selected in this study to benchmark the rainfall prediction performance. These are NB, C4.5, SVM, ANN, and RF, which are all supervised learning methods.
3. A Voting Classifier is created that trains on an ensemble of above models and predicts an output (class) based on their highest probability of chosen class as the output. It simply aggregates the findings of each classifier passed into Voting Classifier and predicts the output class based on the highest majority of voting. The idea is instead of creating separate dedicated models and finding the accuracy for each them, we create a single model which trains by these models and predicts output based on their combined majority of voting for each output class.

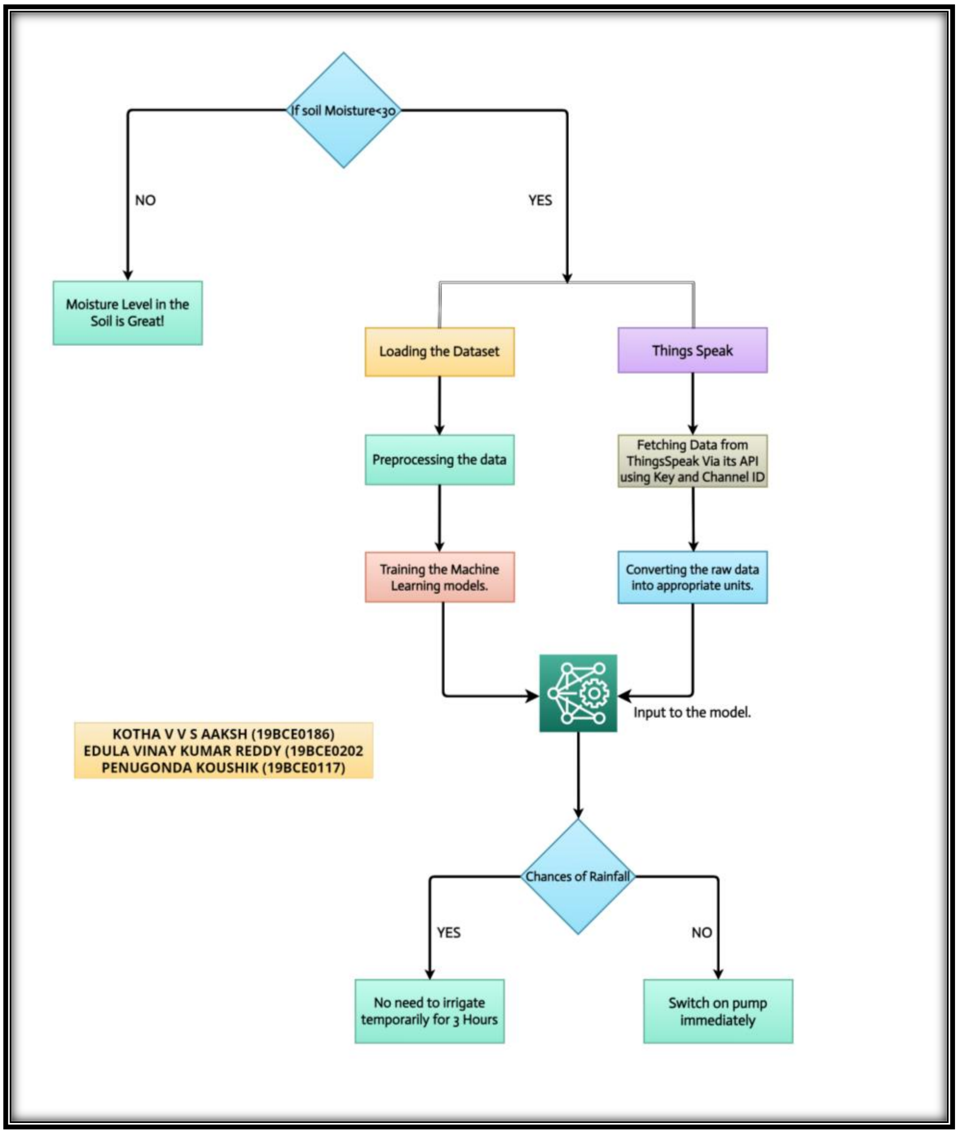


Fig 9: Model Architecture

Step5: Taking the final decision

A motor will turn ON whenever the moisture of the soil drops below some threshold level. Instead of directly turning ON the motor we check probability of rainfall using above mentioned ensemble techniques, if there is chance of rain occurring on that time period we wait for a while. The threshold level will vary from crop to crop. If the particular crop needs more water, then we will set the high threshold level so the crop will get more water. or if the crop needs less water, then we will set a low value.

7. Ensemble Learning Models

Various learning methods are selected in this study to improve the rainfall prediction performance. These are Decision Tree, Naïve Bayes model, Support Vector Machine, Neural Networks, Random Forest which are all supervised machine learning methods. A prominent aspect of the supervised machine learning models is that they select suitable methods together with features and parameters that are deemed suitable. Different fine-tuning parameters are used to tune every classifier in order to produce highly accurate outcomes. A series of tests were carried out to obtain the ideal values of each classifier.

7.1. C4.5 Algorithm:

C4.5 is one of the most efficient classification methods. A decision tree is produced by C4.5 in which every node in the tree splits the classes with respective to the information. Splitting criteria is designated based on the attribute having the maximum normalized information gain. For example, our dataset contains humidity and temperature. The C4.5 algorithm first explores these features to find which feature is the best for splitting data (a feature with maximum information gain). The feature is then again used to split the dataset into the next feature until it reaches the last destination. Table I illustrates the algorithm results.

7.2. Naïve Bayes:

Naïve Bayes is classified as supervised machine learning model that belongs to the family of probabilistic classifiers which applies Naïve Bayes theory to the independence assumption between features of the dataset. Naïve Bayes finds the probability of every feature in the dataset by calculating the assumptions. For every known class label, Naïve Bayes calculates every attribute conditional probability on the class label. Next, it finds the joint conditional probability for the attributes of a label using the product rule. This process is followed by the Naïve Bayes model to obtain the class attributes conditional probabilities. After completing this procedure for each class value, the class having the maximum probability is reported. Table II illustrates the algorithm results.

7.3. Support Vector Machine:

The support vector machine is a machine learning model that divides dataset into two parts with the help of a hyperplane. This partition process independently addresses every class label, and this could be carried out through categorizing the data into class A and not class B, where A and B are the two class labels. The classification is carried out by computing the Euclidean distance between every data point and the hyperplane's margin. The Support Vector Machine model uses a kernel that is a set of scientific functions to allow for data classification in a complex dimensional space when such data could not be linear separable in a lower dimensional space. Various kernel functions are available in machine learning to govern the above, like radial basis function (RBF), sigmoid linear, polynomial and nonlinear. Table III illustrates the algorithm results.

7.4. Random Forest:

Random forest is a machine learning model employed for many purposes, including prediction, regression and classification. This algorithm is an ensemble of decision trees models aiming to create, within the same training data, a multitude of decision tree models and generate the final class as the output. The random forest classifier is tweaked using the number of features to arbitrarily investigate (Num Features), maximum depth of the tree (Max Depth) and the number of tree (Num Tree) parameters. Investigational outcomes reveals that the classification performance of the Random Forest classifier is increased when the number of features, number of trees and depth increases. Table V illustrates the algorithm results.

8. Implementation of prototype

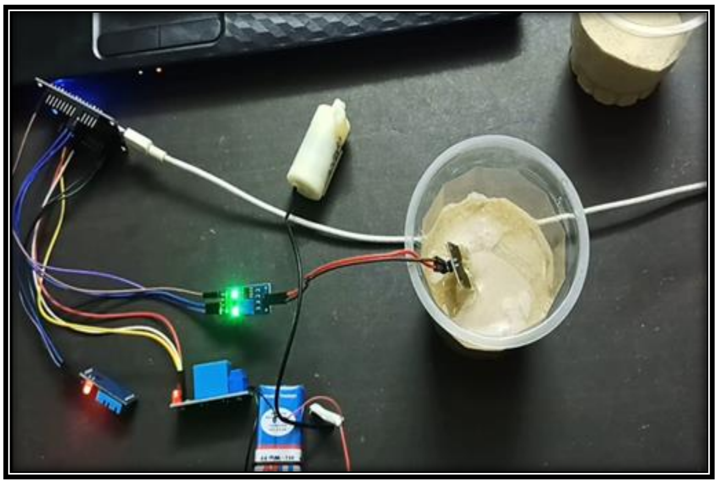


Fig 10: Implementation of Prototype

9. Results and Discussion

C4.5 Algorithm

Accuracy: 0.77

	Precision	Recall	F1-Score	Support
0	0.80	0.88	0.84	274
1	0.64	0.50	0.56	118
Average	0.72	0.69	0.70	392

Table I: Results for the C4.5 Algorithm

Naïve Bayes

Accuracy: 0.81

	Precision	Recall	F1-Score	Support
0	0.84	0.91	0.88	280
1	0.72	0.56	0.63	112
Average	0.78	0.74	0.75	392

Table II: Results for the Naïve Bayes Algorithm

Support Vector Machine

Accuracy: 0.82

	Precision	Recall	F1-Score	Support
0	0.84	0.95	0.89	291
1	0.76	0.47	0.58	101
Average	0.80	0.71	0.73	392

Table III: Results for the Support Vector Machine Algorithm

Random Forest

Accuracy: 0.75

	Precision	Recall	F1-Score	Support
0	0.81	0.85	0.83	278
1	0.58	0.50	0.54	114
Average	0.69	0.67	0.68	392

Table IV: Results for the Random Forest Algorithm

The performance levels of Machine learning based predictions vary between the algorithms, although artificial neural network algorithm has a slight performance advantage compared to other classification models. Each model has some error but collective result is always better because error rate will decrease. When one model fails then other models will rectify it. As we are using ensemble learning we will consider combination of knowledge of different models. A majority Voting model is created that trains on combination of above models and predicts an output (class) based on the majority of highest probability of chosen class as the output by each model. It simply aggregates the results of each machine learning model passed into Voting Classifier and predicts the output class based on the highest majority of voting.

Fig 11,12,13 illustrates the visualization of sensed data through sensors in ThingSpeak. It helps us to make sense of data. We can combine, convert and calculate new data through this data and we can visually understand the relationships among the data using built-in plotting functions. In future, we can also integrate data from multiple channels to build a more sophisticated analysis.

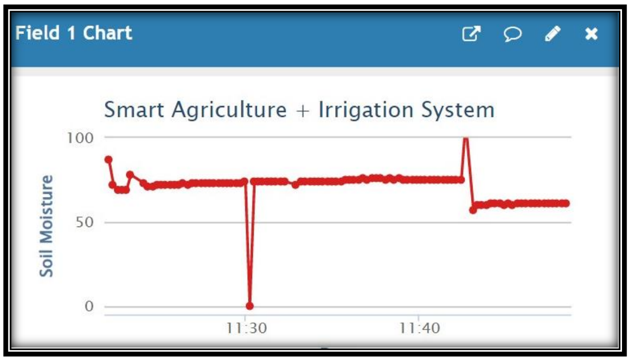


Fig 11: Visualizing Soil Moisture ThingSpeak.

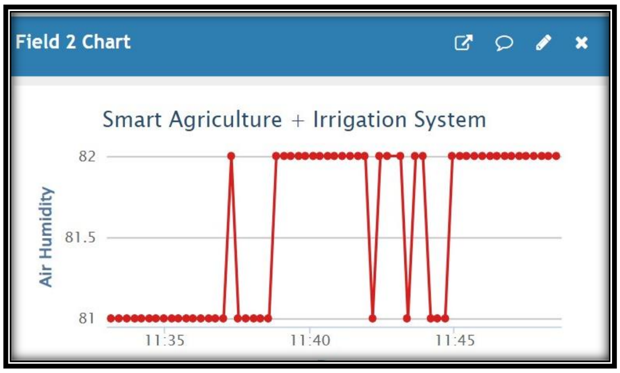


Fig 12: Visualizing Air Humidity in ThingSpeak.

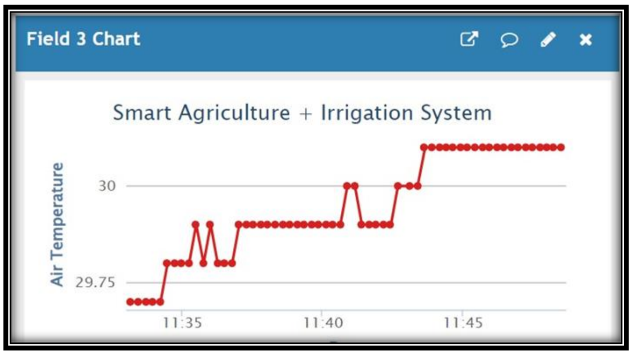
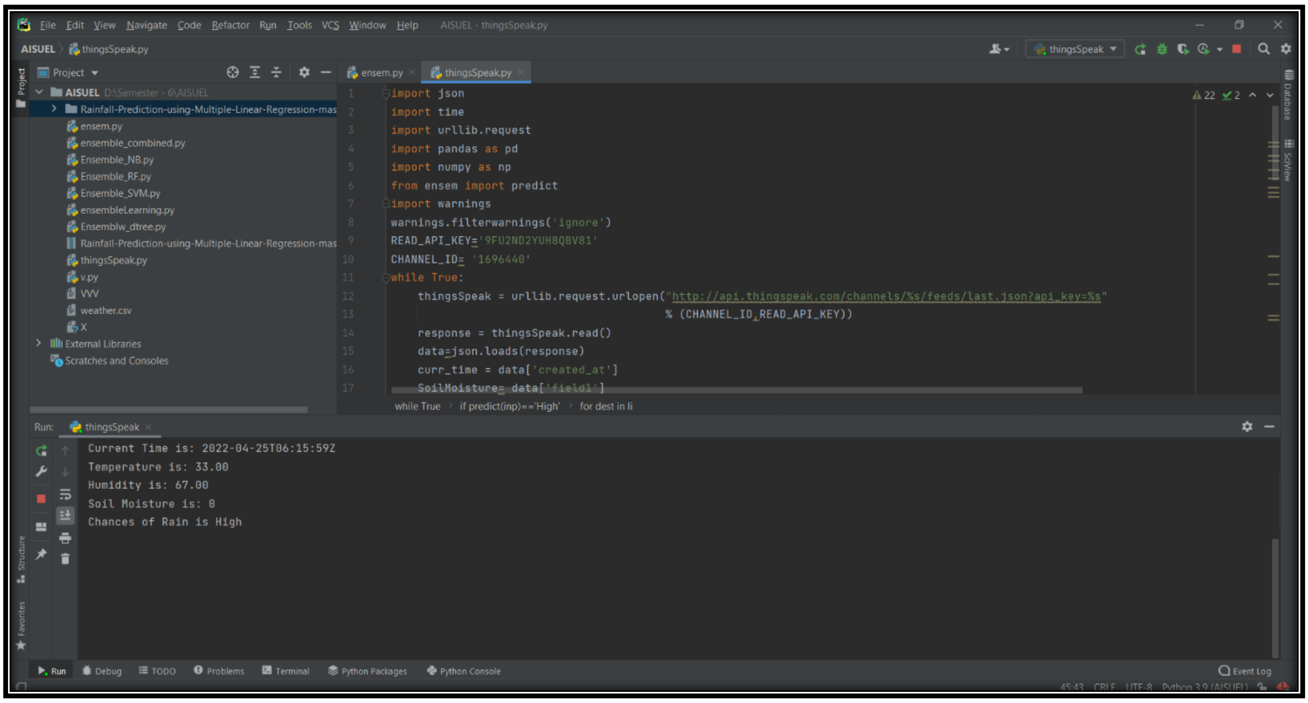


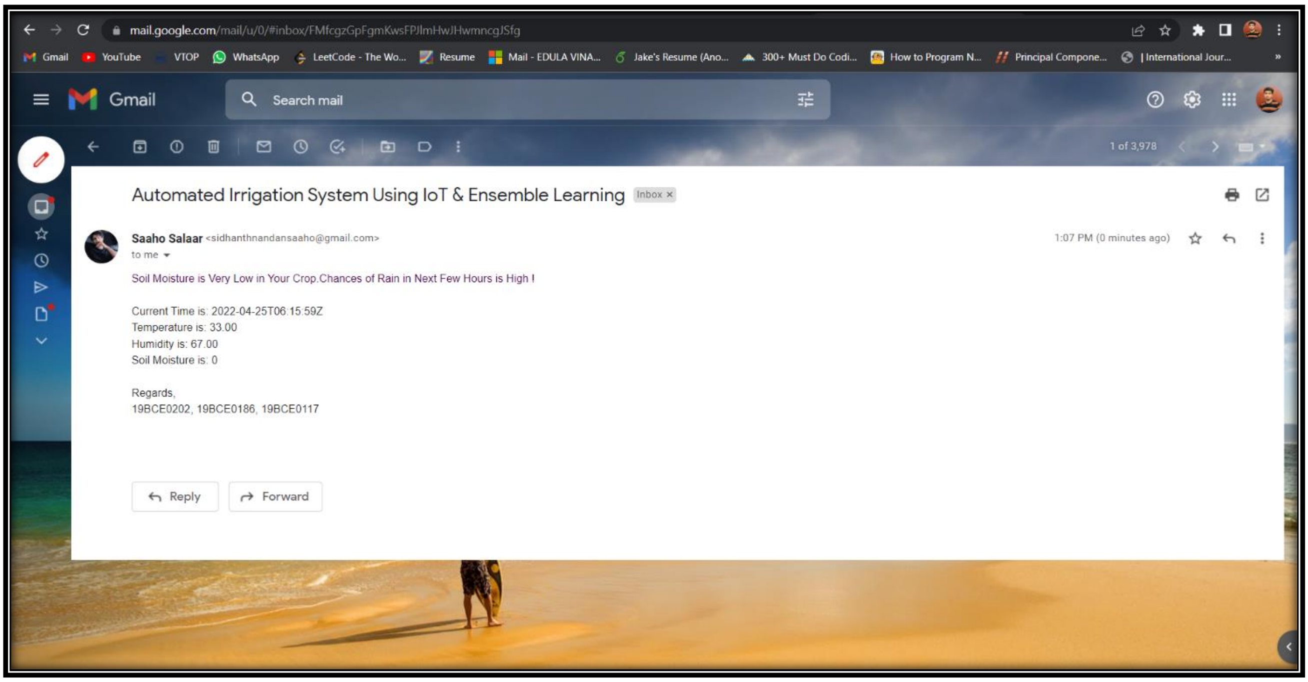
Fig 13: Visualizing Air Temperature in ThingSpeak.

Fig 11, Fig 12 and Fig 13 showing the graphs of percentage of soil Moisture, Air Humidity and Temperature of the field from Thing Speak cloud Respectively.

Output of Ensemble Learning Python Code:



The Mail the Farmer Received after Running the Ensemble Learning Python Code:



As, the Soil Moisture detected is very less (less than the threshold 30), we check the chances of Rainfall, and we obtained that there is some chance of Rainfall; So, we wait for 3 Hours without turning on the Motor.

10. Conclusion

For agriculture, regular updates of the crop like moisture, humidity and temperature are most important. With progression in technologies the climate forecasting data accuracy has improved significantly and the weather forecasting data can be used for prediction of rainfall in that particular area. This project proposes an Automated Irrigation System using Internet of Things and Ensemble learning technique to predict the rainfall chances. The proposed method uses sensors' data of recent past data and the weather forecasted data for prediction of rainfall in near future. We used Ensemble learning technique to predict the chances of rainfall on that day. The main aim of this technique is instead of creating separate dedicated models and finding the classification metrices for each of the models, we create a single model which trains these models and classifies the output based on their combined majority of voting for each output class. The predicted rainfall chances are better in terms of their accuracy and error rate. Further, the prediction algorithm can be integrated into a standalone system prototype. The system prototype is cost effective, as it is based on the open-source technologies. In future, we are planning to conduct a water saving analysis based on proposed methodology with multiple nodes along with minimizing the system cost. The automation in the irrigation system proposed in our approach worked successfully. Its price is also adequate. By using our approach, we can reduce workers in fields for maintenance purpose. This approach will not only automatically irrigate the water based on the moisture level in the soil and rain fall chances but also sends the data to the Thingspeak server to keep track of the land condition by the farmer.

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11. Appendix

11.1. Arduino Program for Sensing the Values & Sending the Data to Cloud:

```
#include <ESP8266WiFi.h>
#include <DHT.h>
#define DHTPIN DHT11
DHT dht(5, DHT11);
String apiKey = "SFVUIL1H83JEJQ36";
const char *ssid = "iPhone"; //ssid: the SSID (Service Set Identifier) is the
name of the WiFi network you want to connect to.
const char *pass = "xxxxxxxx"; //key: a hexadecimal string used as a security
code for connecting to WIFI network.
const char* server = "api.thingspeak.com";
const int SensorPin = A0;
int soilMoistureValue = 0;
int soilmoisturepercent=0;
int relaypin = 2;
WiFiClient client; //Creates a client that can connect to to a specified
internet IP address.

void setup() {

Serial.begin(115200);
pinMode(relaypin, OUTPUT);
dht.begin();


WiFi.begin(ssid, pass); //Initializes the WiFi and provides the current status.

while (WiFi.status() != WL_CONNECTED)  //Return the connection status.Returns
WL_CONNECTED when connected to a network , WL_IDLE_STATUS when not connected to
a network, but powered on
{
delay(500);
Serial.print(".");
}

Serial.println("");
Serial.println("WiFi connected");
delay(4000);
}


void loop()
{
float h = dht.readHumidity();
float t = dht.readTemperature();
Serial.print("Humidity: ");
Serial.println(h);
```

```
Serial.print("Temperature: ");
Serial.println(t);
soilMoistureValue = analogRead(SensorPin);
//Serial.println(soilMoistureValue);
soilmoisturepercent = map(soilMoistureValue, 1024, 280, 0, 100); //Re-maps a
number from one range to another. That is, a value of fromLow would get mapped
to toLow, a value of fromHigh to toHigh, values in-between to values in-
between, etc.
//Serial.println(soilmoisture);
Serial.println("Moistur percent:");
Serial.print(soilmoisturepercent);
Serial.println("%");
if(soilmoisturepercent <= 30)
{
digitalWrite(relaypin, HIGH);
Serial.println("Motor is ON");
}
else if (soilmoisturepercent > 30 && soilmoisturepercent <= 100)
{
digitalWrite(relaypin, LOW);
Serial.println("Motor is OFF");
}
if (client.connect(server, 80))   //Connect to the IP address and port
specified in the constructor. The return value indicates success or failure.
{
String postStr = apiKey;
postStr += "&field1=";
postStr += String(soilmoisturepercent);
postStr += "&field2=";
postStr += String(h);
postStr += "&field3=";
postStr += String(t);
postStr += "&field4=";
postStr += String(relaypin);
postStr += "\r\n\r\n\r\n\r\n";
client.print("POST /update HTTP/1.1\n");  //Print data to the server that a
client is connected to.
client.print("Host: api.thingspeak.com\n");
client.print("Connection: close\n");
client.print("X-THINGSPEAKAPIKEY: " + apiKey + "\n");
client.print("Content-Type: application/x-www-form-urlencoded\n");
client.print("Content-Length: ");
client.print(postStr.length());
client.print("\n\n");
client.print(postStr);
}
client.stop();
}
```

11.2. Python Programs for Ensemble Learning & Data Extraction from Cloud:

❖ thingsSpeak.py

```
import json
import time
import urllib.request
import pandas as pd
import numpy as np
from ensem import predict
import warnings
warnings.filterwarnings('ignore')

READ_API_KEY='9FU2ND2YUH8QBV81'
CHANNEL_ID= '1696440'

while True:
    thingsSpeak =
urllib.request.urlopen("http://api.thingspeak.com/channels/%s/feeds/last.json?a
pi_key=%s"
                                          % (CHANNEL_ID,READ_API_KEY))
    response = thingsSpeak.read()
    data=json.loads(response)
    curr_time = data['created_at']
    SoilMoisture= data['field1']
    Humidity = data['field2']
    Temperature= data['field3']
    print("\nCurrent Time is: " +curr_time+ "\nTemperature is: " +Temperature +
"\nHumidity is: " + Humidity + "\nSoil Moisture is: " + SoilMoisture)
    data = pd.read_csv("weather.csv")
    X = data[['TempAvgF', 'HumidityAvgPercent']]
    Y = data['Events']
    y = []
    for i in Y:
        if 'Rain' in str(i):
            y.append([1])
        else:
            y.append([0])

    Celsius = int(float(Temperature))
    FarenTemp = (Celsius * 9 / 5) + 32
    # Rain->  inp = np.array([[24,79]])
    #No Rain->  inp = np.array([[44,79]])
    inp = np.array([[Temperature], [Humidity]])
    inp = inp.reshape(1, -1)
    print("Chances of Rain is High")
    if predict(inp)=='High':
        import smtplib
        li =
["vinaykumarreddyedula@gmail.com","koushik.penugonda2019@vitstudent.ac.in",
"kothav.vsaakash2019@vitstudent.ac.in"]
```

```
        for dest in li:
            s = smtplib.SMTP('smtp.gmail.com', 587)
            s.starttls()
            s.login("sidhanthnandansaaho@gmail.com", "Test@123")
            subject = "Automated Irrigation System Using IoT & Ensemble
Learning"
            body = "Soil Moisture is Very Low in Your Crop."
            body=body+"Chances of Rain in Next Few Hours is High ! \n"
            body=body + "\nCurrent Time is: " +curr_time+ "\nTemperature is: "
+Temperature + "\nHumidity is: " + Humidity + "\nSoil Moisture is: " +
SoilMoisture
            msg = f"Subject:{subject}\n\n{body}\n\nRegards,\n19BCE0202,
19BCE0186, 19BCE0117".encode(
                'utf-8')
            s.sendmail("sidhanthnandansaaho@gmail.com", dest, msg)
            s.quit()
        print("Email Sent !")
    # print the output.
    time.sleep(500)
    print("\n")
    thingsSpeak.close()
```

❖ **ensem.py**

```
import pandas as pd
from sklearn.ensemble import RandomForestClassifier
from sklearn.naive_bayes import GaussianNB
from sklearn.tree import DecisionTreeClassifier
def predict(xx_test):
    data = pd.read_csv("weather.csv")
    X = data[['TempAvgF', 'HumidityAvgPercent']]
    Y = data['Events']
    y = []
    for i in Y:
        if 'Rain' in str(i):
            y.append([1])
        else:
            y.append([0])
    from sklearn.svm import SVC
    from sklearn.model_selection import train_test_split
    x_train,x_test, y_train, y_test=train_test_split(X,y,test_size=0.30)

    def SVM(x_train,xx_test, y_train):
        model = SVC()
        model.fit(x_train, y_train)
        pred=model.predict(xx_test)
        return pred

    def dtree(x_train,xx_test, y_train):
        decision_tree = DecisionTreeClassifier()
        decision_tree.fit(x_train, y_train)
```

```
        Y_pred = decision_tree.predict(xx_test)
        return Y_pred

    def NBB(x_train,xx_test, y_train):
        gaussian = GaussianNB()
        gaussian.fit(x_train, y_train)
        Y_pred = gaussian.predict(xx_test)
        return Y_pred

    def ranfor(x_train,xx_test, y_train):
        random_forest = RandomForestClassifier(n_estimators=100)
        random_forest.fit(x_train, y_train)
        Y_prediction = random_forest.predict(xx_test)
        return Y_prediction
    lst=[]
    lst.extend([SVM(x_train,xx_test, y_train),dtree(x_train,xx_test,
y_train),NBB(x_train,xx_test, y_train),ranfor(x_train,xx_test, y_train)])
    if lst.count([0])>lst.count([1]):
        return "Low"
    else:
        return "High"
```