Affordable Smart Farming Using IoT and Machine Learning

An AI powered cost-effective solution to improve traditional farming

Reuben Varghese
Department of Computing Science and Engineering
VIT University
Chennai, India
reubenvarghese1@gmail.com

Smarita Sharma
Department of Computing Science and Engineering
VIT University
Chennai, India
smarita.sharma22@gmail.com

***Abstract*—Each year many crops go waste due to a lack of optimal climatic conditions to support crop growth. Losses to the tune of over 11 billion dollars are reported each year in India alone. In this paper, we develop an affordable system which when deployed will give an insight into the real time condition of the crop. The system leverages Internet of Things(IoT) and Machine learning to produce an affordable smart farming module. This system uses state-of-the-art methods in order to improve the accuracy of the results and automate the monitoring of crops thereby requiring minimal human intervention. IoT is used to connect the ground module which includes the sensors to the cloud infrastructure. In the cloud, machine learning based real-time analytics is performed to predict the future condition of the crops based on its past data.**

Keywords—IoT; Affordable Smart Farming; Machine Learning; Predictive Analysis;

I. Introduction

With the advancement of technology in today's world, major improvements are rampant in almost every field ranging from housing to healthcare. Unfortunately, this wand of technology is yet to work its magic in the field of agriculture. Empowering the farmers with some of this technology is a dire need of this era.

Farmers especially in agricultural nations like India (where farming is the primary occupation of over 50% of the population), still rely on their intuition and use techniques that are over a century old for cultivating crops. These techniques demand a huge amount of manual labour and constant supervision by the farmers. Due to this, over 11 billion dollars worth of revenue is lost each year due to crop damage [1]. A primary cause of this is that the plants fail to get the optimal conditions needed and also due to a lack of effective supervision. While previously, research has been done in this domain, the solutions proposed do not keep in mind the economic status of the average farmer in these nations [2][3].

Over the past few years, rapid climatic changes have been experienced. In India, this manifestation is in the form of an erratic monsoon. Various parts of the country get unpredicted amounts of rainfall and the farmers are generally unprepared. As the atmospheric conditions keep changing rapidly, farmers fall prey to the lack of knowledge that is required to estimate what kind of farm conditions, techniques and soil type is essential for growing a type of crop. Moreover, every so often it happens that farmers over utilize a particular piece of land to such an extent that it leaves the land devoid of all minerals. Hence, it is important to be able to predict and forecast the performance of the crop for all kinds of environmental conditions. This proposed model provides a solution by building a hardware based system which on deployment will estimate the amount of water present in the soil in real time, detect the humidity level and temperature of the environment. If the amount of water or temperature/humidity in the soil or the environment drops below the threshold point , then the system will alert the user(who in this paper is assumed to be the farmer) by sending an SMS to him. This method is similar to the method used by A. N. Arvindan et al. [4]. The farmer can further monitor the status of the crops using an android app or web application. The second part of the project deals with the prediction of crop type as per the soil conditions. This system uses state-of-the-art methods in order to improve the accuracy of the results and provide minimalistic human intervention.

With the help of IoT and machine learning, a smart, reliable yet low cost novel solution is developed which is capable of automating several procedures from the watering of crops to predicting the health of the crop. This system is also capable of predicting the condition and the type of crop optimal for a particular type of soil and environment with the help of machine learning. The farmer will also have complete control of the various equipment present in the field globally with the help of the internet.

II. Related Work

A. *UAV-Based Crop and Weed Classification*

Philipp et al [5] emphasizes on the use of low cost UAV system with vision-based classification for the segregation of essential crops from weed. It aims at reducing the indiscriminate spread of herbicides and pesticides on crops in order to preserve their quality. Several methods like crop detection has been used where the image of the crop is selectively masked out of the background that includes soil and other objects. Then, the vegetation mask undergoes feature extraction, mainly using 2 methods: Objects-based or Keypoint-based. In addition to this, further geometric features are extracted by deploying the spatial relationship between the crops. Differences in distance and azimuths between the query objects or the keypoints and neighbouring query objects/keypoints is generated and used as input for the classification which is the final step. Finally, the features vectors extracted are fed to random forest classification that helps in multi-classification. In this process a large number of decision trees are generated at the time of training which finally helps output the probability of each class label.

B. *A Data-Driven Approach to Soil Moisture Collection and Prediction*

Zhihao et al [6] has made use of data-driven methods to build a soil moisture framework using SVM(Support Vector Machine) and RVM(Relevance Vector machine) [7] for early prediction of the soil moisture level based upon the environmental conditions. The data is collected using wireless sensor nodes and has been tested on the Illinois historical data. This framework is resilient and sustains its accuracy for around 45 days.

III. Software And Components

This section describes the set of hardware components and the specifications for setting up a cost effective cloud based infrastructure.

A. *Cloud Infrastructure*

a. An Amazon AWS T2.Micro EC2 instance [8] is setup. The web application is deployed on this server. It also acts as a database for storing the data received. This data is later used for as test data for the predictive analysis.

b. In places with limited internet access, a cloud based solution might not be practical. In such situations, the whole web application may be deployed on a single raspberry pi. To further improve the cost efficiency, this same raspberry pi may also be used to collect the sensor inputs. This Raspberry Pi will be connected to the LAN network that exists in the farm. Unfortunately, a major drawback of this scheme is the lack of access to the real-time data as well as lack of control over the farm equipment once the farmer is outside the farm. There is no cost effective solution as of today that can ensure global access to the data without internet access. Hence, the use of the internet over a private network is highly encouraged for this task. Even in regions where internet access is available, the farmer may choose to use a raspberry pi as a server for the data collection and for the hosting of the website but in this case, the data can be accessed globally.

B. *Hardware Components*

a. Raspberry Pi 3:
   i. A Raspberry Pi is a cost effective yet, reasonably powerful solution that is perfect for this use case.
   ii. This model of the small single-board pc is especially useful because it has a built-in wifi module. This enables us to save on the cost of an extra wifi module that would have been needed otherwise.

b. Sensors Used:
   i. DHT-11:

      This sensor is used to read the temperature and humidity near the crop.

      The data is received in the form of digital waves.

   ii. FC-28:

      This sensor is used to detect the amount of moisture present in the soil in which plant is kept.

      It has two electrodes which are placed in the soil. Based on the amount of moisture present in the soil,the conductivity between the two electrodes varies. This change in conductivity is reflected in the output which is an analog signal.

Since the output of this sensor is an analog wave, this sensor cannot be directly interfaced with a Raspberry Pi and hence an Analog-To-Digital converter is used which converts the signal into a form that is readable by the Raspberry Pi.

iii. MQ-135:

The MQ-135 is a cheap but efficient way to detect the air quality. It is capable of sensing the presence of various gases.

iv. LM-393:

The LM-393 sensor is used to monitor the amount of sunlight the plant is receiving and based on this amount, it can be determined whether the crop is receiving an optimal amount of light that is needed for its proper growth.

c. 5V-10A Relay Module:

This Relay module is used as a switch to control the farm equipment.

It uses an electromagnet to change the state of a large amount of current using a relatively much smaller amount of current.

d. Analog-to-digital converter:

An analog to digital converter is a device that converts an analog input signal to a digital output signal. This device is used to convert the analog signals received from the sensors into digital signal so that they may be read by the Raspberry Pi.

In this implementation, an arduino is used as it contains an in-built analog-to-digital converter.

However, for improving the cost effectiveness of the system, an MCP -3208 ADC chip may be used.

C. Software:

a. Python: Python 3 must be installed on the server. This is used to run and train the machine learning models.
b. Tensorflow: It is an open-source machine learning library developed by the Google Brain Team. A python implementation of this library is to be installed for implemententing the predictive analysis tasks.
c. Apache Server: This is used to create a Nginx server.

IV. Proposed Model

Gilt-edged crop growth depends on various factors from the kind of soil the crop grows in to the amount of moisture it receives.

For detecting predicting the kind of crop that will be suitable to grow on the agricultural land, we employ a method similar to that used by Pudmular et al [9].

The dataset used consisted of soil specific details of different regions of India. It also consisted of the optimal soil and moisture conditions needed along with the type of soil required for growing a particular crop.

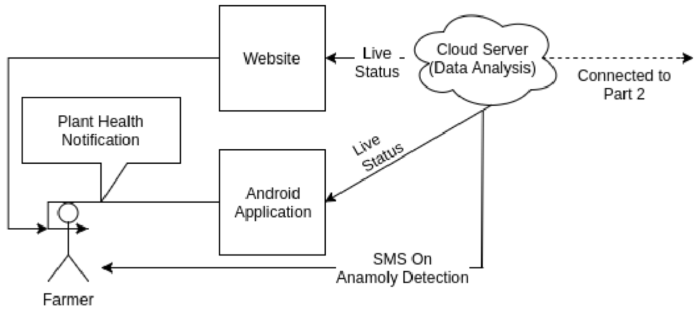

Figure 1(a). User-Side Architecture

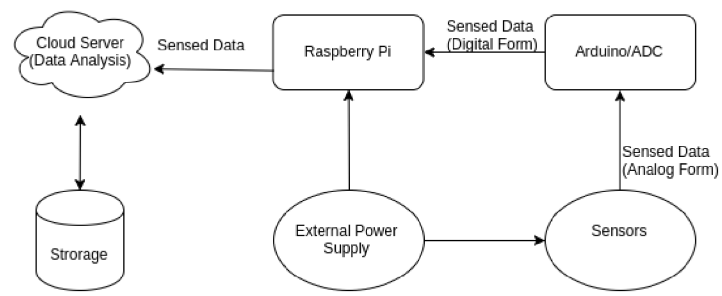

Figure 1(b). Field-Side Architecture

The different crops considered are millets, pulses, groundnut, wheat , cotton, paddy and sugarcane.

Given this dataset, we train a logistic regression based model using Tensorflow that takes the condition of the soil, temperature, moisture and the soil that is to be grown as input and predicts whether the conditions are optimal for such a crop. We also train a Support Vector Machine(SVM) [10] which takes the current soil conditions as input and suggests the optimal plants for the given soil conditions as output.

The data sensed by the sensors is stored as elements of a Numpy array. After every Y seconds, the data sensed by the sensors is pushed to the cloud server for analysis. Here Y is a value chosen based on the bandwidth and speed of the network present at the farm. Since network speed is never constant, the value of Y is not constant. It changes based on the speed of the network that is checked each hour using python.

$$Y \propto \frac{1}{Network\ speed}$$

A logistic regression model is trained to take the sensor values as input and predict whether the crop is receiving all the optimal conditions.

Based on the prediction, the model also predicts as to which condition is not being met. Accordingly, the necessary steps are taken automatically. For example, suppose it is predicted that the amount of moisture is low, the water pump is automatically turned on so that the plant receives enough moisture.

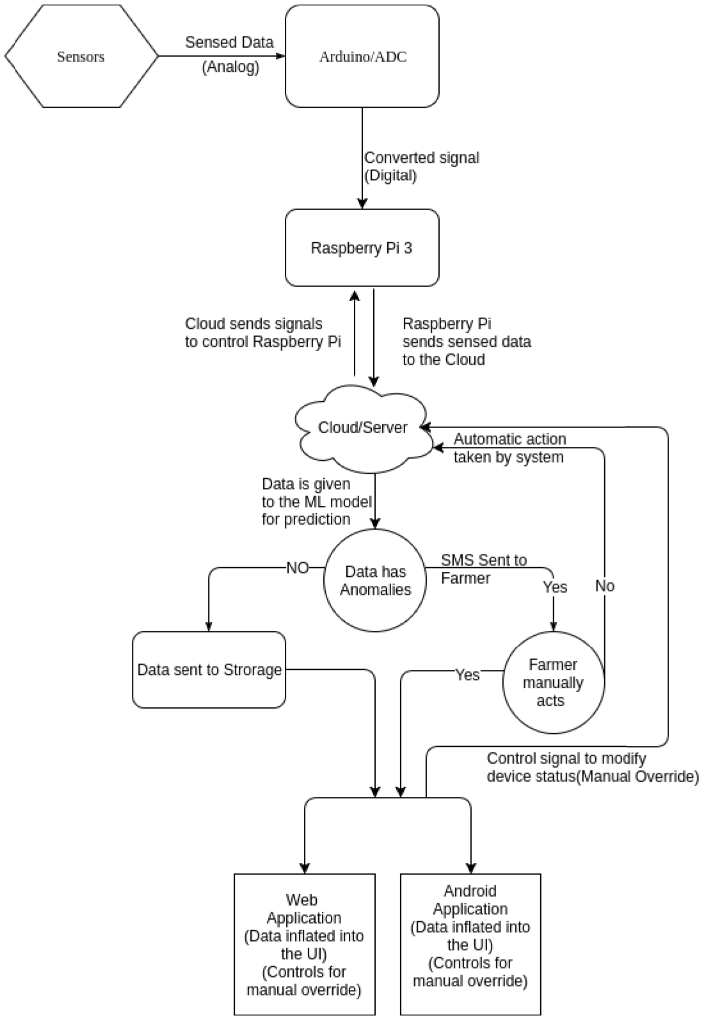

Figure 2. Flow of the proposed system

When the system detects an anomaly, the first step taken is to send an SMS to the farmer informing him about the condition that is not being met. It may be noted that since the farmer is not assumed to have any prior technical knowledge, the SMS sent to him contains a sentence mentioning the condition that is not being met instead of the raw sensor values. The farmer may then choose to act manually and override the system to solve the problem or may choose not to act.

If after a set duration, no action has been taken from the farmer's side, the system manually takes the necessary action to bring back optimal conditions for the plant growth.

The SMS is sent using an SMS API which is free of cost and using which a person may send upto 100 free messages each day.

To detect whether the conditions are optimal or not, a pre trained SVM is used as a classifier. It takes the crop name , sensor values as input and the output consists of a particular class which it predicts the crop's current condition to be in.

The various classes are hot, thirsty, optimal. It may be noted that the soil moisture is detected as a range and hence can be mapped to any defined range. For this project, the range chosen was 0-255 where 255 is the output when a lot of moisture is detected and 0 is the output when no moisture is detected. Under optimal conditions, the soil moisture content should be anywhere between 125 - 210 depending on the type of crop bring grown.

- Web application : The web application is developed using PHP as backend. A simple file based logging system is used to store the data. This is done so as to reduce the reliance on a dedicated database for this purpose. This has been done so as to ensure that the system runs well even on devices like Raspberry Pi with extremely limited set of resources and storage. By eliminating the need of a database that is running as a background process all the time, significant amount of processing power is saved. This ensures that the server load is minimal.

  The farmer may manually control the machinery in the field through the web application. A timer may also be set for turning on/off all the appliances.

  This feature of having a timer is unique to this model and has not been proposed before to the best knowledge of the authors. This feature can help save significant amount of electricity and crops.

  The web application can also be used to view the current status of the crop at any time. However, it may be noted that the web application should not be given the highest priority as many farmers will not have access to a computer. Hence, the android application should be given the highest priority and must be considered as a more reliable alternative.

- Android Application: The android application is the primary link between the crop and the farmer. It is through this application that the farmer controls and monitors the condition of the plant from anywhere in the world.

  It has a number of functionalities:

  - Present the farmer with the current status of the crop. The current status also includes visual modifications such as highlighting of the status text with a particular colour to denote the severity of the condition of the crop. For example: Red indicates that plant is not in a good condition and is in need of immediate attention, green indicates that the conditions around the plant are optimal for its growth.
  - The application also contains multiple switches using which the farmer may choose to change the state of the devices located in the farm from the comfort of his home.
  - The application also features a timer using which a farmer may set the duration for which he wants a particular state change. Once the timer expires, the state of the device is automatically changed by the system with no intervention needed by the farmer.

V. Future Work

With the advancement of computer vision, a few additional features to have would be to be able to understand the kind of soil and the type of seed using just an image. Computer vision [11] can also be used to detect disturbances in the farm. For example, it can be used to detect some birds or animals that might be damaging the crops [12]. Another major possible improvement would be to fabricate a Printed Circuit Board especially for this application and ensuring that it is safe inside the soil using water proofing among other things. The fabrication of a printed circuit board(PCB) for this task will increase the efficiency and reduce the cost of the overall project.

VI. Conclusion

A very efficient solution for ensuring affordable smart farming has been developed. The novelty of the solution proposed lies in the cost efficiency and practicality of the project. This project ultimately aims at reducing the amount of manual labour required to be done by the farmer. It also aims at helping the farmer be more at ease about his crops by giving him real time updates and complete control over his field from anywhere in the world.

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