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IoT and Machine Learning approaches for Automation of Farm Irrigation System

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Abstract

In the current age of high competition and risk in markets, technological advancements are a must for better growth and sustainability. The same applies to the agriculture industry. Every farmer has high stakes on the crops, their yield and quality. Rising water issues and need for proper methodologies for farm maintenance is a hot issue that needs to be tackled at utmost propriety. An automation of irrigation systems in farms is proposed in this research. The proposed solution is based on the Internet of Things (IoT), which would be a cheaper and more precise solution to the farm needs. A Monitoring system whose main purpose is to solve the over irrigation, soil erosion and crop-specific irrigation problem will be developed to ease and efficiently manage Irrigation problems. Since it is a well-known fact that the water is a scarce resource and over wastage of such an essential resource should be minimized. The proposed solution will be developed by establishing a distributed wireless sensor network (WSN), wherein each region of the farm would be covered by various sensor modules which will be transmitting data on a common server. Machine learning (ML) algorithms will support predictions for irrigation patterns based on crops and weather scenarios. So, a sustainable approach to irrigation is provided in this paper.

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Keywords: IoT;WSN;Machine Learning;Algorithms;Technology,Agriculture.

1. Introduction

Farming and agriculture accounts for a major portion of GDP (Gross Domestic Product) not only of developing countries but also for many developed nations. Thus, improvising and optimizing the current farming technologies is the need of the hour. It will not only help in flourishing sustainable development of mankind, flora and fauna but will also help in dealing with the global crisis such as climate change and epidemics such as draught. With better technology comes better yield; thus, will help prevent situations like starvation and malnutrition. The technology should be available at an affordable price so that its impact could reach to billions of people worldwide. The smart home systems are being extensively research and developed but this major area of Agriculture and specially Smart Agriculture tends to lag behind other domains and require quite a lot of R&D to achieve sustainable goals not only at industrial level but at the root level of this agriculture industry. Automation of conventional irrigation techniques can lead to many folds increase in crop yield. This paper proposes a state-of-the-art solution to the farm Irrigation using IoT (Internet of Things) and Machine Learning techniques, a wireless sensor network field needs to be established throughout the farm field or even in the household garden to monitor all the parts of the field, The proposed research presents the best possible solution to the farm needs, irrigation needs based on various open source databases available online and Machine learning algorithms(Classification and Regression). Irrigation needs varies with the crops and that too with the seasons. During various phases of crop production, crop water needs vary substantially. Over Irrigation or less irrigation both would affect the yield and the nature, so automation of Irrigation systems is necessary. Efficient Irrigation ensures a sustainable use of water and also helps in replenishing groundwater. Irrigation based on soil topology and weather pattern is shown in the study conducted by using various sensor modules and various micro-controllers[1] like Raspberry Pi, Arduino Uno and Arduino Mega. This paper presents an economical and easy to understand approach of automating irrigation systems[2]. These chips along with the sensors, transducers and actuators monitors, controls soil temperature, moisture and soil fertility[3]. The solution proposed in this research study is based on Literature Review and experimentation of high-quality research articles and Machine learning algorithms[4]. Pros and cons of various sensors, micro-controller used for dealing with various problems of farming and irrigation are described in this research. The paper explores the vast potential of technology in agriculture.

The paper is further organized into following sections: section 2. provides the detailed Literature review, section 3. proposes the solution to smart farming requirements. Section 4 describes the result of this research. Section 5 lists all the challenges to the proposed solution and research. Section 6 Concludes the paper along with the future scope of the study.

2. Literature Review

A comprehensive literature review has been done and some of the efficient possible technologies and algorithms based on literature review and experimentation are suggested in the paper for the development of Smart Farm Monitoring System. Ersin et al.[1] proposed the micro-controller based irrigation system which is very efficient and economical compared to other conventional methods, precision irrigation approaches have been described by Liu et al.[5].Smart irrigation system with the help raspberry pi and Arduino was proposed by Agrawal et al.[2].Micro-controller based irrigation approach had been presented by Koprda et al.[6], Farm pest detection with the help of the ultrasonic sensors is described by Ahouandjinou et al.[7].A complete overall architecture of IoT based irrigation system was proposed by Goap et al.[8].Machine Learning approaches for soil classification had been provided by Smith et al.[4].A farm vehicle and smart dispatching approach have been researched by Wu et al.[9]. Ryu et al. [10] provided with an interconnected approached towards smart farming. Kwok et al. [11] work suggested plant detection using deep learning and then based on plant type its appropriate irrigation amount required. Deep learning and altitude based economical irrigation approach has been discussed in the research by Wang, Muzzammel, Raheel et al.[12]. Martinell et al. described a WSN approach for precision farming [13]. The smart farming approach based on cloud and edge computing was presented by Izquierdo et al. [14]. Detailed smart farming approach had been described by Bacco[15] in their research work, all the challenges, enablers and opportunities were discussed. Thus, after an exhaustive study of currently available literature, that deals with the current farming problems and their respective solution, this paper highlights and provides a combined, precise view to the possible solution for farming needs. Paper provides the details of a distributed sensor network field whose prototype was developed for this study.

3. Proposed Work

The proposed solution relies on the 2 types of micro- controllers namely Raspberry pi 3 and Arduino Mega, the choice of micro-controller is based on their computational power, cost and ease of availability. With the use of various sensors, the variable parameters will be constantly monitored and irrigation suitable to and specific to the type of crop will be done. The following Fig.1. provides the major enablers of the proposed work.

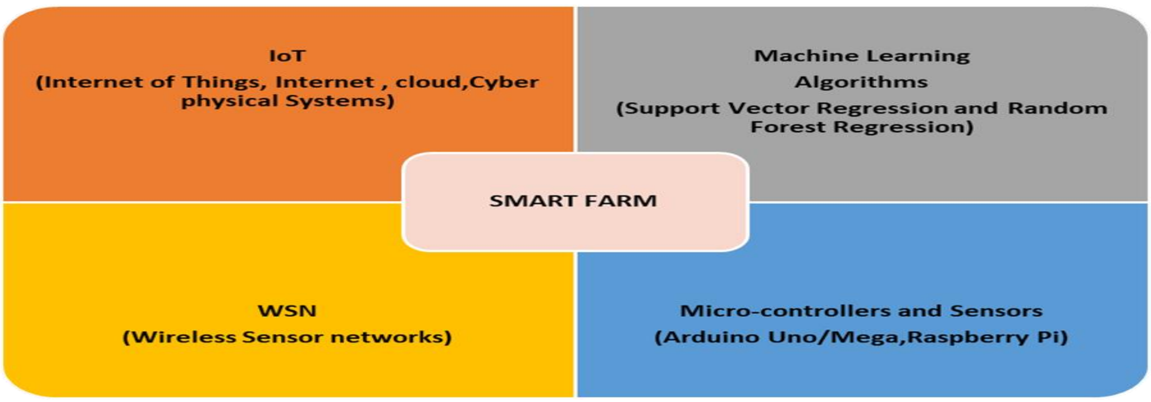

Fig. 1. Technology enablers for Smart Farm Irrigation.

3.1. Application Architecture

The first step for the implementation of a Smart irrigation system for farm automation is laying the wireless sensor network field in which each node is inter connected by Wi-Fi module and lays data over a common server, from where an automated python script can keep polling the data and then send alert/start signal for the required operation. The fig.2. represents an overall topology of various sensors nodes, however the actual network topology depends upon the demographics of the region.

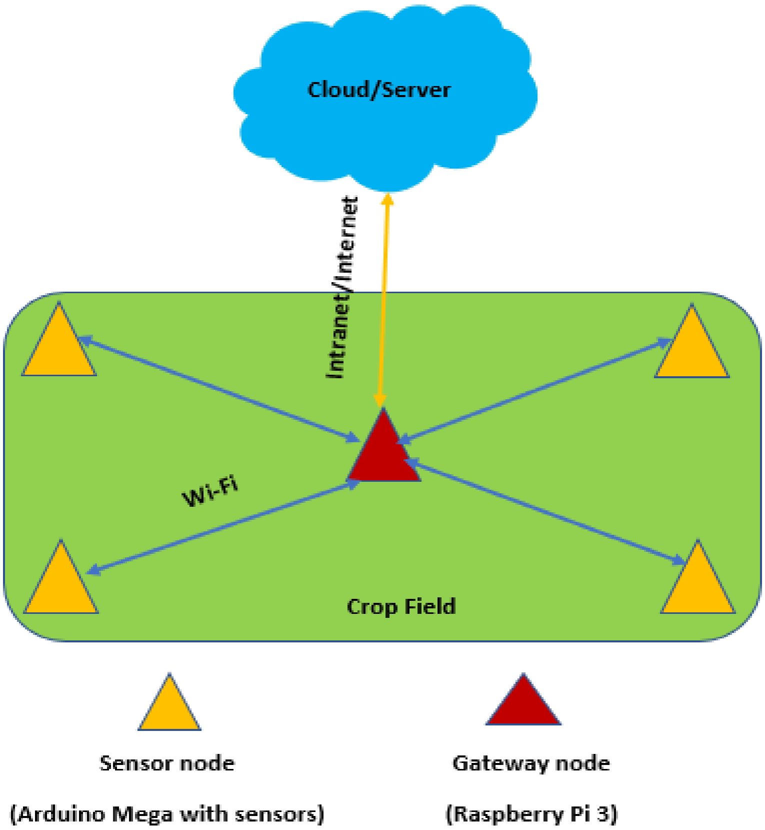

Fig. 2. Diagrammatic representation of distributed WSN.

The first step towards establishing an automatic irrigation system is collecting data through various sensors attached throughout the field or the garden. Raspberry pi 3 B+ will act as the gate way node responsible for communicating with all other sensor nodes(Arduino Mega 2560 Rev3)[1].Each Arduino mega unit consist of advance soil moisture sensor, Wi-Fi module ,GSM module, Bluetooth module, Temp and Humidity, MQ2 gas sensor, Water Level indicator, Alarm, Clock module, Battery, Relay module. Ultra-sonic sensor for detection of major intruders as well as rodents. Each of the node will relay the information to the gateway node/ base station which is raspberry pi 3,the python script in raspberry pi will be responsible to store the data in the server/cloud , from where the data can be presented to the end user via an application layer. For data transmission from raspberry pi to the server internet is not a must requirement, intranet can also do the proposed work, so it can be used at places where there is no or very less internet connectivity. The connection of various sensors to the micro-controller is based on the fundamental concept of receiver , transmitter, ground and positive ,most of the connections are to be done in the same way and Arduino mega provides ample number of RXD,TXD,digital and analog pins along with a number of V_{cc} and Gnd pins. The first phase of the suggested application is completed after establishing the network topology and the collection of the data. The collection of data through various sensors is the preliminary and the first step for data processing.

3.1.1. Structure of Each Node

Each node consists of a micro-controller which is suggested to be Arduino mega in this study as it best suites the scope of the solution but depending upon the scale of implementation one can also choose from other alternatives such as Arduino Uno R3 and Node mcu. Every node is connected to Wi-Fi module,DHT11 sensor, MQ2 gas sensor and Battery module. The Block diagram of each node is given in fig.3.

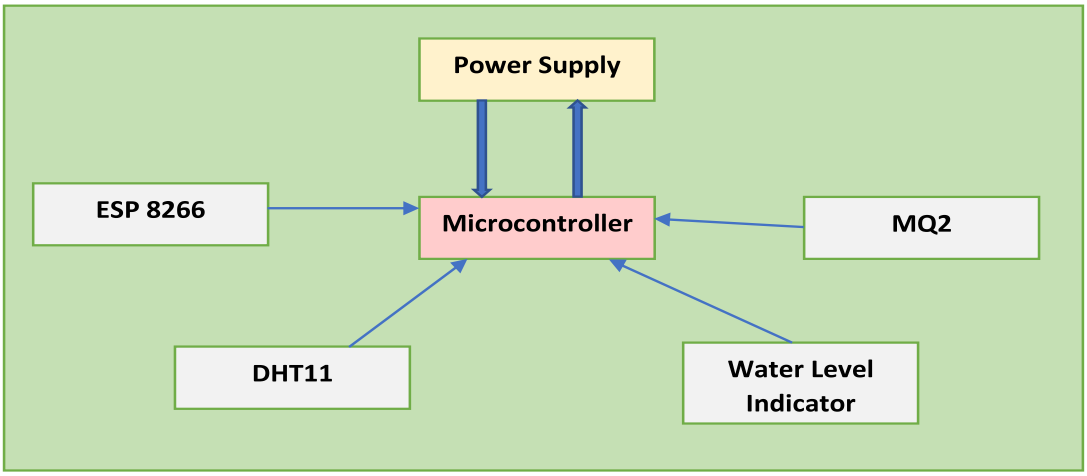

Fig. 3. Configuration of Each sensor node

3.2. Data Processing

All the data that has been gathered by the sensors needs to be analyzed and processed so that the further signal can be send to the actuators as well as alerts can be sent to the end user in case if manual intrusion is necessary. The fig. 4. represents the flow diagram of the overall system. The python script running in the raspberry pi will check for various conditions from the data received from the nodes as well as the web. Weather data will be continuously fetched from online open source API's and if the weather indicates a probability of rain more than 98% then the field will not be irrigated but as a safety measure if the humidity drops below a certain threshold for a specific crop ,then the field will be irrigated. The Irrigation would be based on soil type and crop specific, also for automating the systems, the soil type would be determined using Machine Learning Algorithms. The best algorithm for soil type classification[4] as per literature review is Support vector classification. Thus, after processing of all the parameters a control signal from the gateway node (Raspberry Pi 3 B+) to the actuators (Solenoidal Valve etc.) which will start the water pump. Continuous polling of soil humidity will be there based on fixed time interval and after certain level of humidity the irrigation will be stopped.

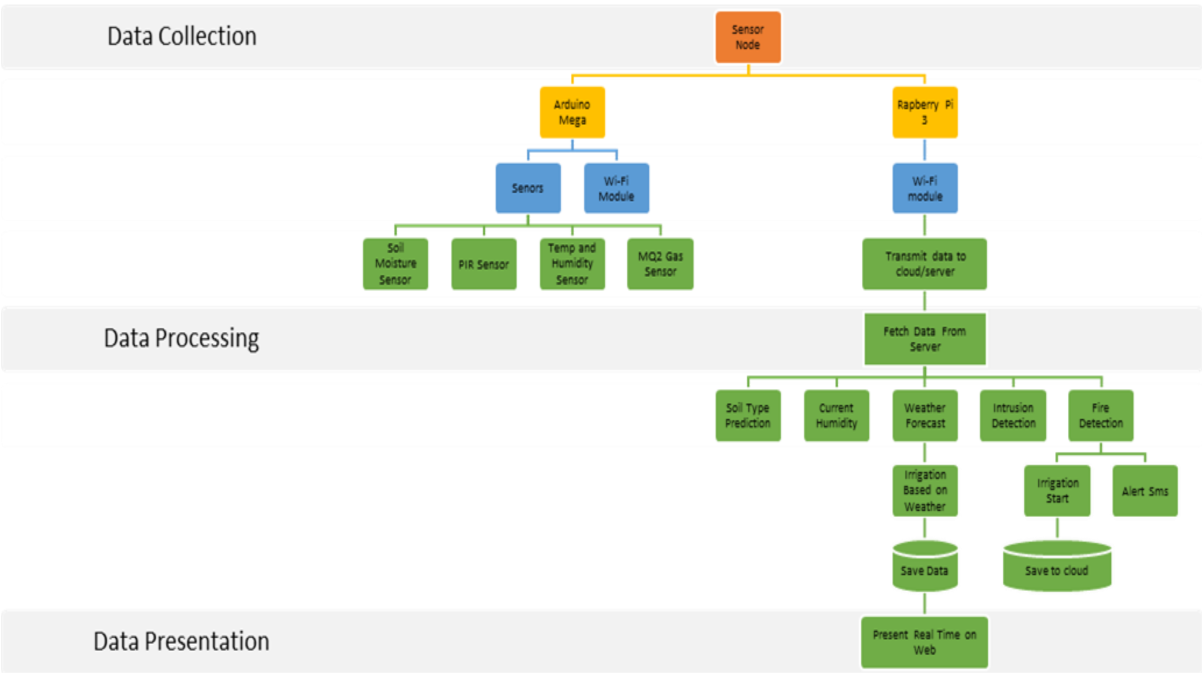

Fig. 4. Activity Flow Diagram Smart Farm

3.2.1. Indian Agriculture Data Analysis

For understanding the various crops grown in India and their production quantity and cost aspects an exploratory data analysis is done on "Agriculture Production in India "[19] dataset available on Kaggle. The analysis is done in python and visualizations are created using Tableau. This analysis lays the foundation of significance and need for automation in the sector to reduce cost and increase productivity. Fig.5. represents the graphical results of data analysis.

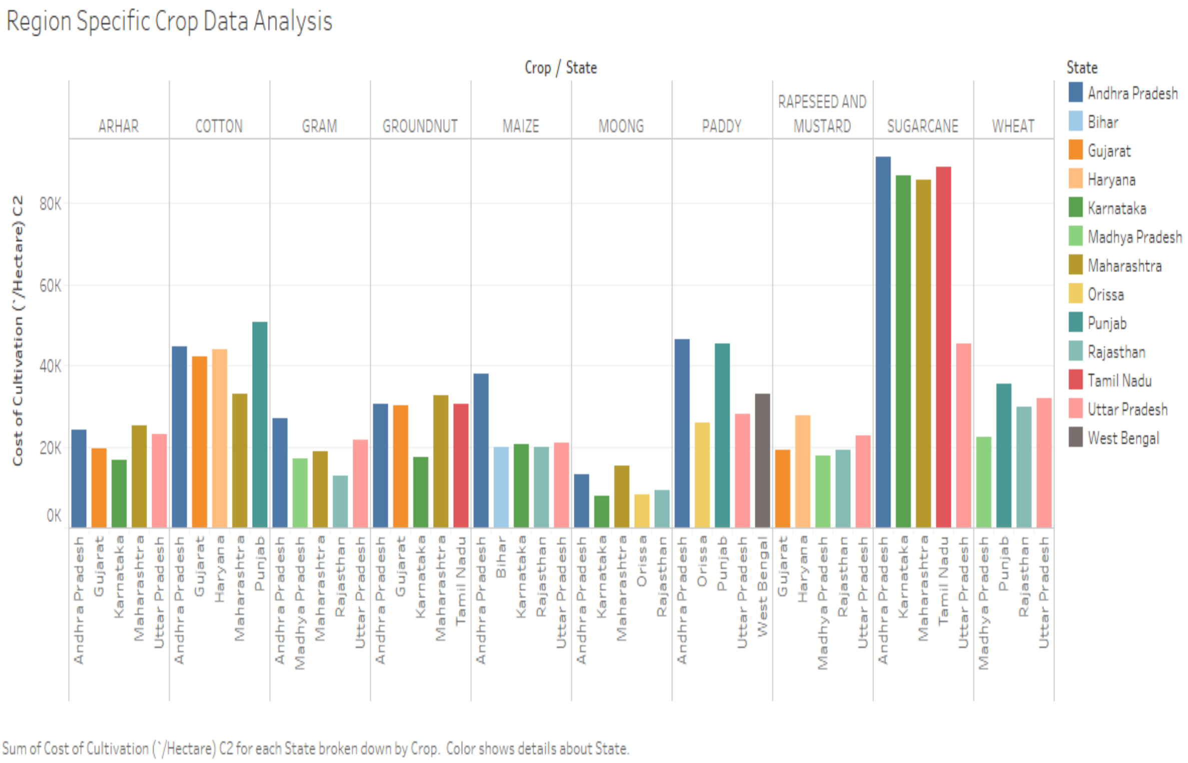

Fig. 5. Region Specific Crop Data Analysis

3.2.2. Soil Moisture and Weather Data Processing

The soil humidity is being measured using DHT11(Digital Humidity and Temperature) sensor, which measures both humidity and temperature. DHT11 gives RH % which helps in determining the current state of irrigation as well as the exact need of more water resource. DHT11 RH % generally ranges from 20% to 90%. To save and use energy, resources more efficiently machine learning algorithms were applied on the previously collected humidity states, so as to optimize the crop irrigation. For predicting the soil moisture, a comparative study of multiple linear regression and Support vector regression[16] and random forest regression[17] was carried out, which gave the following results as shown in fig. 6.

Actual Relative Humidity %	Precipitation %	Predicted RH%
38	0	30
33	66	58
67	98	75
45	0	38
86	54	74
71	92	78

Fig. 6. Relative Humidity prediction for Irrigation decision

The best algorithm for predicting the relative humidity based on the past data and the precipitation probability fetched from open source weather API providers using R programming and rvest package of R. The predictions are made by considering past day relative humidity and precipitation probability, The Table depicts data of certain observations from DHT11 sensor carried out during experimentation phase and the precipitation data fetched from online open sources. For More specific crop irrigation, the formula[18]:

$$EV_o \times C_f = W_{need} \quad (1)$$

Where EV_o is the evapo- transpiration reference, C_f is crop factor and W_{need} is the per day water need of the crops, since this paper proposes to automated farm monitoring and irrigation is one of the most significant activity in agriculture so it needs to be taken care of with high accuracy. The crop type , weather conditions and the growth stage of crop plays a significant role in the amount of water required and thus the generic approach towards water needs of crops tends to provide wrong details. C. Brouwer et. al.[18] gave the complete detail about irrigation management and their approaches provides some of the best possible ways for irrigation. Thus with exact water need data, irrigation is to be carried out in an efficient and sustainable manner.

3.3. Data Presentation

The data needs to be available on a dynamic website, which will represent the real time data analytics and the time stamped irrigation pattern so that in case of any anomaly corrective measures can be taken easily. Visual line graphs tend to provide a temperature and humidity values with the time stamps thus enabling an easy to understand, fast and agile implementation of the system. The fig. 7. represents the sample temperature graph of raspberry pi 3.

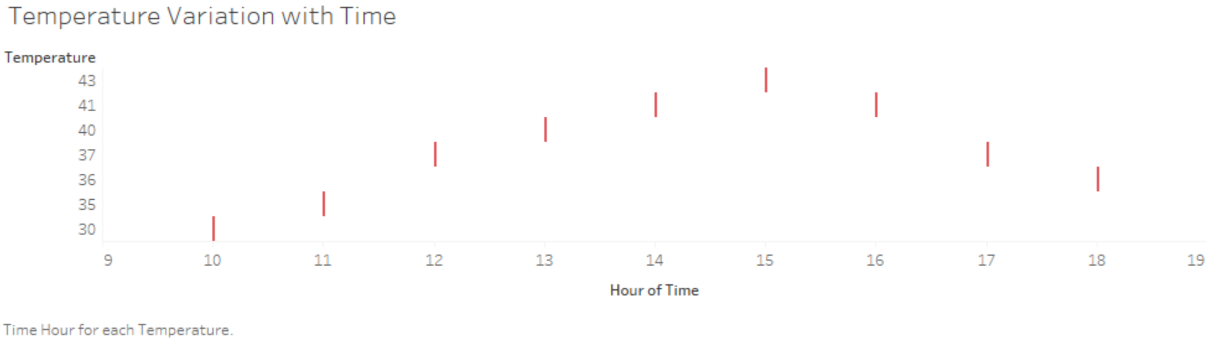

Fig. 7. Temperature variation at Different Times

4. Result

An automated farm monitoring system is developed which is a sustainable solution to various existing and un-for seen epidemics such as starvation due to food shortages and economic crisis. IoT and Machine learning algorithms such as SVM (Support Vector Machine) and SVR (Support Vector Regression) with Radial basis function kernel helps in classification and quantitative predictions of soil type, crop type and amount of irrigation required by the crops. The analysis of “Agriculture Production in India “dataset gives the information about the agriculture industry in different regions of India. The comparative analysis of various algorithms suggests that Random forest regression gives the reasonable accuracy of 81.6% and the highest F score for predicting RH(%), compared to other algorithms. The p value given by the model for independent variables and dependent variable is less than the significance level of 0.05. A smart farming approach that could help everyone from a large-scale farming industry to a small-scale farmer to even household garden owners. The inter-connectivity of various devices ensures a smooth flow of all activities at an ease. The soil moisture prediction results are shown in fig.8.

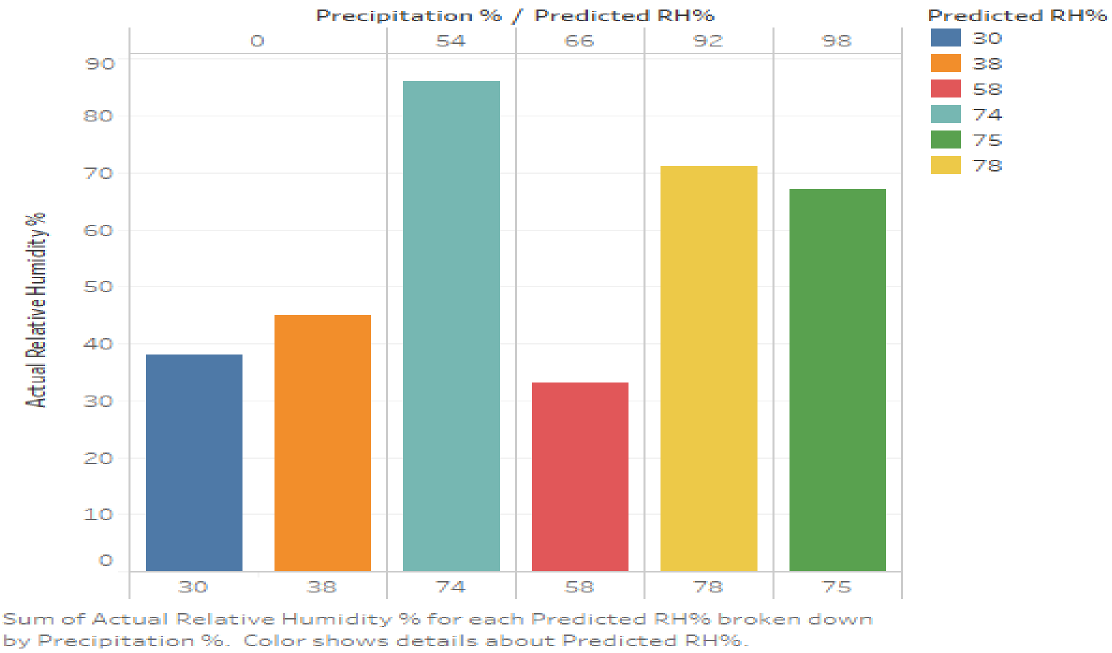

Fig. 8. Actual vs Predicted soil moisture Graph

5. Challenges to the proposed work

- Extreme weather conditions pose a serious threat to the solution proposed in this research.
- The prediction accuracy depends upon the proper installation of the setup.
- Machine learning algorithm needs to be trained on large as well as region specific data.
- Wild animals also pose as threat to the hardware although they would be detected upon entering the field but requires manual intervention to prevent any kind of damage to the hardware.
- A dedicated server / network storage needs to be there for the visualization purpose.
- Un-availability of structured data of crop water needs.
- The accuracy of model prediction depends on data available
- The SVR accuracy depends on the hyper-parameters and type of kernel selected.

6. Conclusion and Future Work

This research paper presents an economical approach towards automating the agriculture industry, it provides a sustainable and computationally efficient approach based on Internet of Things based. Establishing a proper distributed network contributes to the accuracy of the predictions made by SVR, Random Forrest Regressor. Sensor node inter-connectivity will help monitor the complete field thoroughly. To implement a system which would be mobile and can help in every stage of farming i.e. from sowing of seeds to reaping of crops is proposed as future work. Use of tools for automating predictions with the help of hyper parameter tuning and ensemble learning is suggested as a future work in this research study. A mobile, dynamic and robust approach towards the proposed automation represents the future scope.

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