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Intelligent IoT Based Automated Irrigation System

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Abstract

Agriculture has a major impact on economy of the country. Lot of Research been carried out in automating the irrigation system by employing wireless sensor and mobile computing. Also research been done in applying machine learning in agricultural system too

Recently "Machine to machine (M2M)" communicationn is an emerging technology which allows devices, objects etc to communicate among each other and send data to Server or Cloud through the Core Network.

So accordingly we here have developed an Intelligent IoT based Automated Irrigation system where sensor data pertaining to soil moisture and temperature captured and accordingly KNN (K- Nearest Neighbor) classification machine learning algorithm deployed for analyzing the sensor data for prediction towards irrigating the soil with water. This is a fully automated where devices communicate among themselves and apply the intelligence in irrigating. This has been developed using low cost embedded devices like Arduino Uno, Raspberry Pi3.

Keywords: M2M, K-Means, Arduino, Raspberry Pi3

INTRODUCTION

Agriculture is the major backbone of Indian Economy. Most of the available fresh water resources are used in Agriculture.In India most of the irrigation systems are operated manually which is not automated. In the recent years automated and semi- automated technologies been deployed for irrigating the field which has replaced the traditional Agricultural mechanism.

The available traditional methods of irrigation are drip irrigation, ditch irrigation, sprinkler system. This problem can be easily rectified by making use of the automated system rather than the traditional systems..

The current irrigation methodology adopted employ uniform water distribution [1,2] which is not optimal. So accordingly technologies being applied towards agricultural monitoring which is required by farmers.

So as such standalone monitoring station been developed employing "MSP 430" microcontroller along with set of meteorological sensors which includes temperature and humidity.

In addition to the standalone monitoring station, Wireless Sensor based monitoring system [3] been developed which is composed of number of wireless sensor nodes and a gateway. This system here provides a unique, wireless and easy solution with better spatial and temporal resolutions

In addition to employing technologies in monitoring the agriculture for automating the irrigation system, there is need for some intelligence which allows machines to apply some intelligence in interpreting agricultural data captured and accordingly analyze data towards predicting the output rather than following traditional rule based algorithm.

So towards this, "Machine learning" [4] which is a part of Artificial intelligence plays a key role which allows devices to learn without being explicitly programmed..

Machine learning got its applications in Crop Selection and Yield where many effective Machine algorithms [5-7] identify the input and accordingly output the relationship in Crop selection yielding the approximated prediction

There are other Machine learning techniques like Artificial Neural Networks (ANN), K-Nearest Neighbor and Decision trees which has been applied in Crop Selection based on various factors.

Machine learning also got its application in Crop Disease prediction [8] in addition to Crop Selection and Yield. Crop Disease detection and classification in early stage been carried out using Support Vector Machines. Also disease detection of Crop leaves been carried out using Pattern Recognition which is a branch of Machine Learning.

So it is clear that Wireless sensor based system and machine learning have been employed in agricultural monitoring pertaining to Crop Selection and Yield, Crop disease prediction. But there has been no research reported so far which does prediction and analysis of the agricultural data gathered towards automating the irrigation. Also most of the systems so far are semi automated or in some cases automated which are confined to a small area and there is still need of some human intervention based on prediction for actuating and so.

So now with the upcoming of M2M [9] which is a part of IoT that allow devices to communicate with other devices without the need of human intervention, we here have developed an Intelligent IoT based Automated Irrigation system where Moisture and Temperature sensor been deployed in the agriculture field towards capturing the data for watering the field. Now based on information gathered by the gateway unit from sensor, information sent to control unit which is Raspberry pi. Raspberry pi holds a KNN (K- Nearest Neighbor) machine learning algorithm towards analysis of information extracted from the sensor for actuating the pump for watering the field. This information on data analyzed is recorded in Cloud server which allows the farmer's to access from their mobile handset. This shows a complete intelligent IoT based Automated Irrigation system prototype developed where intelligence developed in training the data set for predicting the soil condition towards watering the field or not which makes things simpler for farmer of not worrying about watering the field. Also the famer's can view the agricultural field watered or not from web server too.

LITERATURE SURVEY

Before going into the details of our Intelligent IoT based Automated Irrigation system, we will review some of the existing system in vogue pertaining to Agriculture.

Traditional Agricultural Monitoring

In some of the traditional irrigation system, irrigation is scheduled by monitoring the soil and water status by employing tension meter and drip irrigation by automating the controller system in sandy soil.

In some irrigation system, fuzzy logic controller [10] been implemented for an efficient irrigation system for field having different crops. Fuzzy logic increases the accuracy of measured value and accordingly assists in decision making.

Green house based modern agriculture need to be precisely controlled in terms of humidity and temperature. The atmospheric conditions of plants inside the green house vary from place to place which makes it difficult towards maintaining uniformity at all places in farmhouse manually. So towards this, GSM been used towards reporting the status about irrigation for farmer's mobile handset

ICT Based Agricultural Monitoring

Sensor based paddy growth monitoring system [11] been developed by researchers Kait towards improving the rice productivity or yield. This system been considered to be cost effective as well as durable at outdoor operations. The architecture of the system is shown in Figure 1 where sensor nodes like Temperature, humidity, light, water level etc are deployed in the field to gather the appropriate data and accordingly transmitted to the Base station using multi hop routing. The data are processed locally at the BS which are then sent to the remote server for further processing and analysis.

After data analysis, message sent to farmers notifying the field conditions and providing suggestions.. Knowledge base can be created based on the data collected using Expert systems for further analysis. This system is not scalable and cannot be reused on other applications as it is not based on the concept of Machine to Machine Communications (M2M) which cover a large geographical area with many sensors deployed in the field.

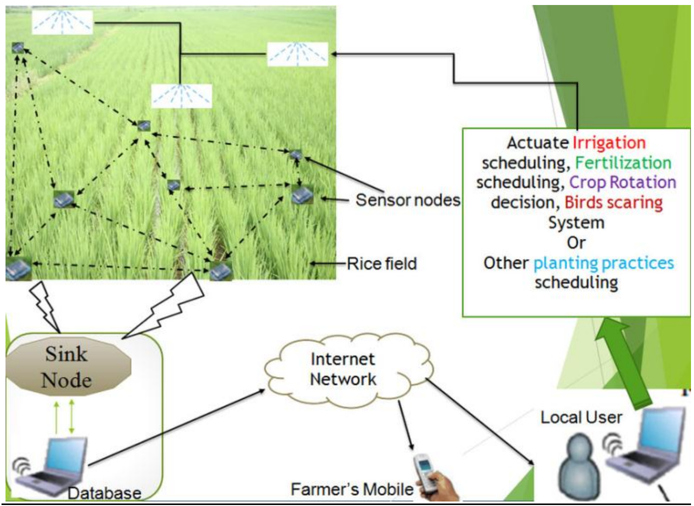

Figure 1: Paddy Growth Monitoring System

Research [12] been carried out by employing Bluetooth Wireless Transmitter that sense soil moisture, temperature etc and accordingly send the data to the Base station (BS) which makes the decision towards irrigation decision based on field and time. The irrigation control unit which is responsible towards irrigating the field pertaining to operating the sprinkler would receive the control signal from the BS. This is based on water Requirement of the fields. Some researchers are also working towards Variable rate Sensor based Irrigation System.

Researchers Wall and King [13] developed an automated field specific irrigation system with soil moisture sensor and sprinkler valve controller. These systems do not take into consideration monitoring the water pollution in lakes or rivers and also do not consider M2M Communication concept. Research been carried out in developing an intensive sensor based irrigation monitoring system which is scalable and self organizing [14]

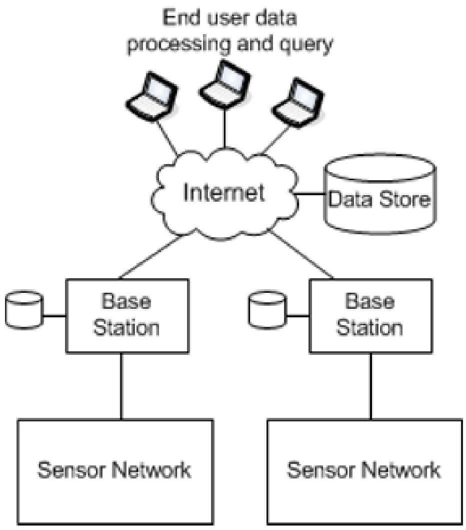

Figure 2: Bottom layer of irrigation monitoring system

The system architecture of their proposed sensor-based irrigation monitoring system is divided into two layers: bottom layer and upper layer as shown in Figures 2 and 3. Hierarchical sensor network are placed in bottom layer where nodes are placed in widely separated clusters. These nodes send the data to Base station (BS) which are connected Wireless LAN that holds the data logger software.[14].

Upper layer consist of five modules which are "acquisition module, network management module, alarm/network status display module and business module". Real and non-real time data are collected using the data gathering modules from sensor network which are stored in database for decision/alert notifications. Alert notifications or displaying information to the end users are carried out by the Alarm/Network status display module. The Alarm/Network status display module acts as an access point between end users and other modules/networks

The condition of networks such as localisations, collision and network configuration are carried out by network management module. This system here developed have introduced the concept of M2M communication where water and energy conserved by using intelligent sensor network and efficient routing protocol

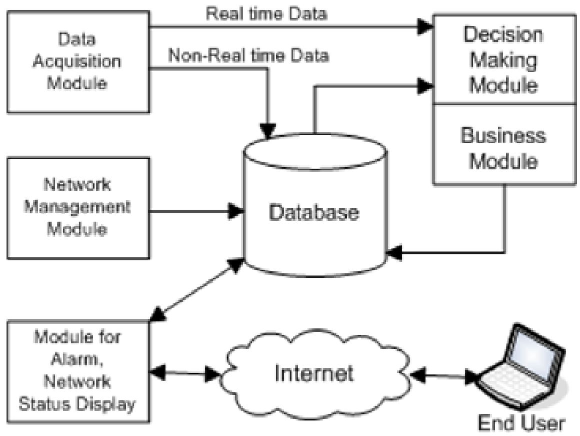

Figure 3: Upper layer of irrigation monitoring system

Research also been done in Crop field assessment towards irrigations, applying fertilizers and pesticides. So accordingly a sensor network based field management system been developed where solar powered moisture nodes and low resolution camera deployed. The information from the two sources are captured for comparative assessment and analysis. Crop height, coverage and greenery information are sent through the sensor networks to the Base Station (BS) by means of Self contained, self powered low resolution camera. In addition crop images are sent from these camera nodes by allocating the time. Lastly the cattle position and behaviour can be observed by means of camera nodes.

Research [15] also been carried out by developing an automated irrigation system (A2S) which is based on sensor network. Wireless sensors are being employed for monitoring and controlling the agricultural fields. The management sub system controls the sensor network and accordingly provides service to farmer's by means of PDA. In this system, long distance communicated provided by means of WLAN between sensor network and server. Management subsystems consist of database, application and web server. Data from sensors are received by the application server which are stored in the database server. Web server is accessed by farmer's using PDA.

In addition to the above mentioned research employing wireless sensors in agricultural monitoring, mobile phones also have been adopted in many rural areas by the farmers [16]. In one of the research, information about the seeds is delivered to the farmer's in two ways. First is the periodic broadcast of seed information from web-portal through SMS on mobile phones of farmers depending upon the season. Second, farmer can query the system by sending names of the crops in SMS and our system will automatically reply with the available seed information of the crop. So this way farmer will be able to get information on their mobile phones at a reasonable cost as compared to expenses incurred in travelling to agricultural offices. Moreover, wastage in time is also an issue that will be solved through this system

Low cost technological solutions are provided by sensor networks for PA towards in field crop management. These crop conditions/growth are monitored for a longer period of time, remotely make decision and accordingly evaluate the potential of new crops. With the data collected by sensors, database or knowledge base created. GUIs are integrated with these sensor networks in these monitoring systems.

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Machine Learning in Agricultural Monitoring

The machine learning algorithm has various uses in the field of agriculture monitoring which are being discussed here.

In one of the research [17], Machine learning been applied towards Grape cultivation. In here farmers are unable to identify the disease manually on the grapes. The disease on grapes is identifiable only after the infection which takes lot of time and also has adverse effect on the vineyards. So accordingly a monitoring system developed for grape cultivation where temperature, relative humidity and leaf wetness sensors are deployed in the vineyard. The data collected at regular intervals are sent using Zigbee module to the server. The server here employs the hidden markov model algorithm towards training the data sets pertaining to Temperature, relative humidity and leaf wetness for analysing the data towards predicting the chance of disease on grapes before getting infected. This information is sent as alert message via sms to the farmer and expert. The system employs machine learning in early and accurate detection of disease in grapes and suggests pesticide to protect the crop from disease and reduce manual disease detection efforts. Also this system can be helpful for farmer's towards giving information on schedule of fertilizer's, pesticide spraying, irrigation etc which would help in improving the quality and quantity of grapes.

Extreme Machine Learning [8] been employed which is a simple, reliable and efficient single hidden layer feed forward neural networks. This methodology is based on weather factors and time series of soil moisture. Data sets are obtained from Dookie Applied Orchard in Victoria, Australia. Results have shown that future trend of soil moisture can be predicted accurately and accordingly decision support can be developed for irrigation scheduling. This method provides better accuracy compared to Support Vector machines which is the traditional and conventional soil moisture forecasting

In another research [19], Random Forest Machine algorithm been developed for detection and classification of different Grape diseases like Anthracnose, Powdery Mildew and Downy Mildew from the images collected under uncontrolled environment with random background. In here, the performance of Random forest been compared with Probabilistic Neural Network, Back propagation Neural Network and Support Vector Machine. Also performance of different texture features been studied. The proposed system achieves best classification accuracy of 86% using Random Forest and GLCM features for background separation and disease classification.

Crop Selection Method research [20] been developed towards selecting the sequence of crops planted over a season. Selection of Crops resolved based on prediction yield rate which is dependent on parameters like weather, soil type, water density, crop type etc. Crop, Sowing time, plantation days and predicted yield rate are given as input for the season in this method and accordingly sequence of crops given as output. The performance and accurancy of CSM is dependent on predicted value of influenced parameters.

Intelligent IoT Based Irrigation System

The existing Agricultural monitoring system has employed wireless sensors for monitoring the soil condition for irrigation. Also some of the system has employed mobile handset also for delivery. In none of these systems, there exists intelligence which analyses the real time data based on past experience for irrigating the field. Most of the system just captures the data from the field and accordingly controls the sprinkler valve for watering the field.

In terms of machine learning, lot of research been carried out towards crop yield and crop disease prediction only. There has been no research reported which employs machine learning algorithm towards analysing the soil condition based on trained data set for irrigating the field automatically without any human intervention. Also there exists no M2M system which interacts between the system towards making analysis and predicting intelligently.

So taking all the above mentioned drawbacks in the existing system, we here have developed an intelligent IoT based automated irrigation system where the temperature and moisture sensors deployed in field communicate to Arduino microcontroller. The sensed moisture and temperature value is then transmitted using serial communication to Edge device called Raspberry Pi3. Raspberry Pi3 holds the machine learning algorithm called KNN (K Nearest Neighbour) classification which takes the soil moisture and temperature into consideration. The KNN (K-Nearest Neighbour) algorithm classifies the objects based on closest training examples in feature space. This is a type of instance based learning or lazy learning where the function is approximated locally. In addition the computation is deferred until classification. This is the most fundamental and simplest classification technique where little or prior knowledge about distribution of data is needed.

So towards making an intelligent analysis for irrigating the field, different soil conditions i.e Dry, little Dry, little wet and Wet are taken for training the data set pertaining to soil moisture and temperature and accordingly predicting the soil based on real time data received for actuating the pump for watering the field.

Finally the analysed data along with field irrigated are updated in cloud server which lets the farmer know the condition of soil and also water being irrigated. This can be accessed from farmer's mobile. Also graph data sheet of moisture versus temperature and CSV file pertaining to trained data set are stored in cloud server too. The complete system architecture of our IoT based System is shown in Figure 4.

The system here consists of three components. First component is the Arduino Microcontroller part where Soil Moisture and Temperature Sensor deployed in soil are connected to Microcontroller which gives the moisture and temperature output based on soil condition and Temperature. The data received by Arduino are then sent to Edge level processor called the Raspberry Pi3 using Serial communication which is second component. In Pi3, K-NN Machine learning algorithm been employed for predicting the soil condition based on Moisture and Temperature level. The predicted output is then used for sending the control signal via the serial communication to Arduino for controlling water pump for watering the field accordingly. The last and final component is recording the soil moisture and Temperature level and prediction with date and time in the cloud server for farmer's to access from their mobile to have good knowledge and understanding on field being irrigated. The corresponding Data Flow Diagram, Sequence diagram, Context diagram and Use case diagram pertaining to IoT based system are shown in Figures 5 to 8. The flowchart of complete IoT based Automated Irrigation system is shown in Fig.9.

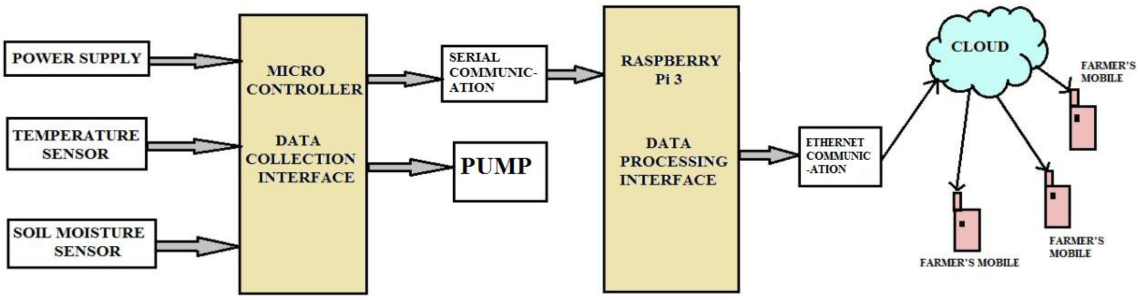

Figure 4: IoT Based Automated Irrigation System

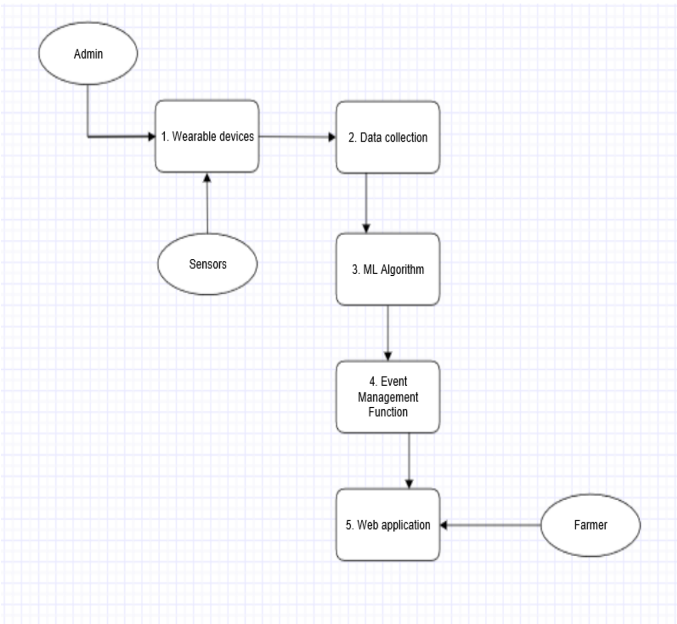

Figure 5: Data Flow Diagram

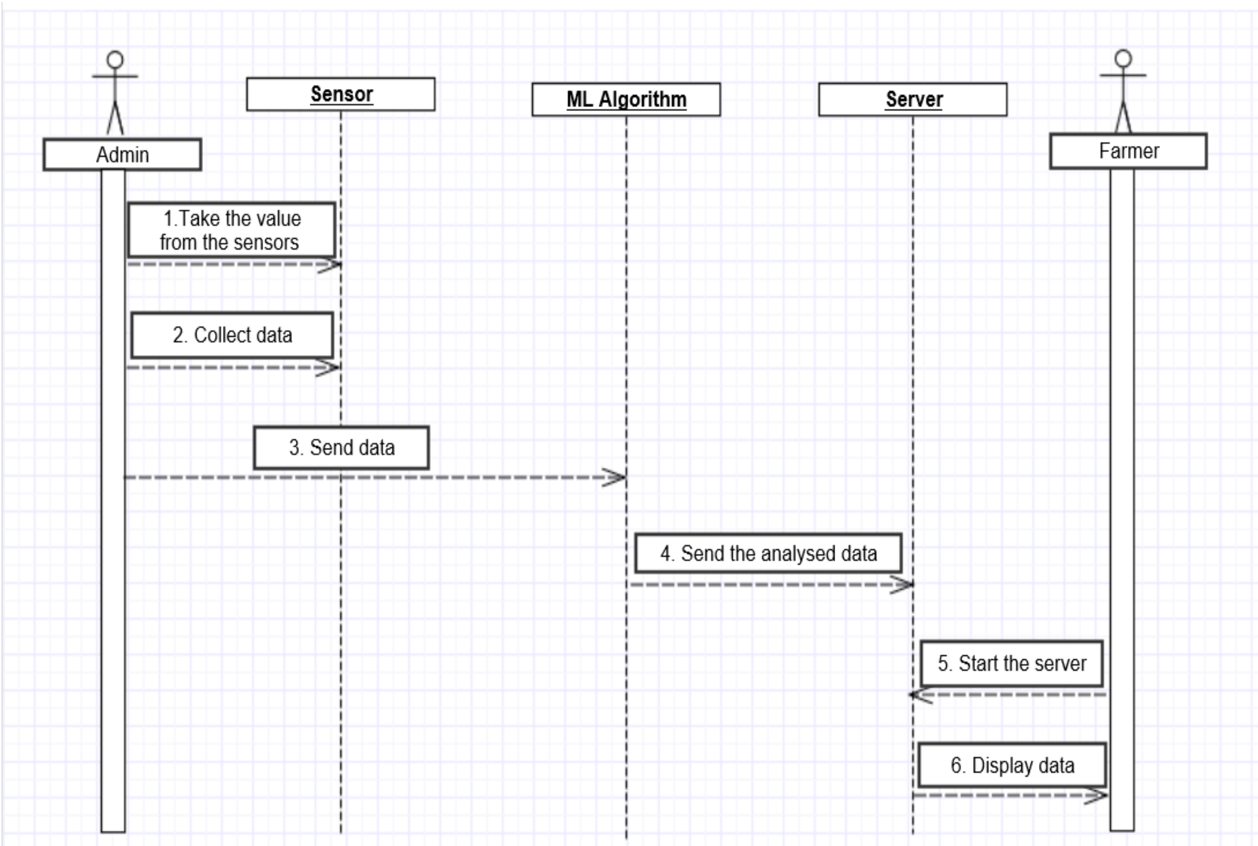

Figure 6: Sequence Diagram

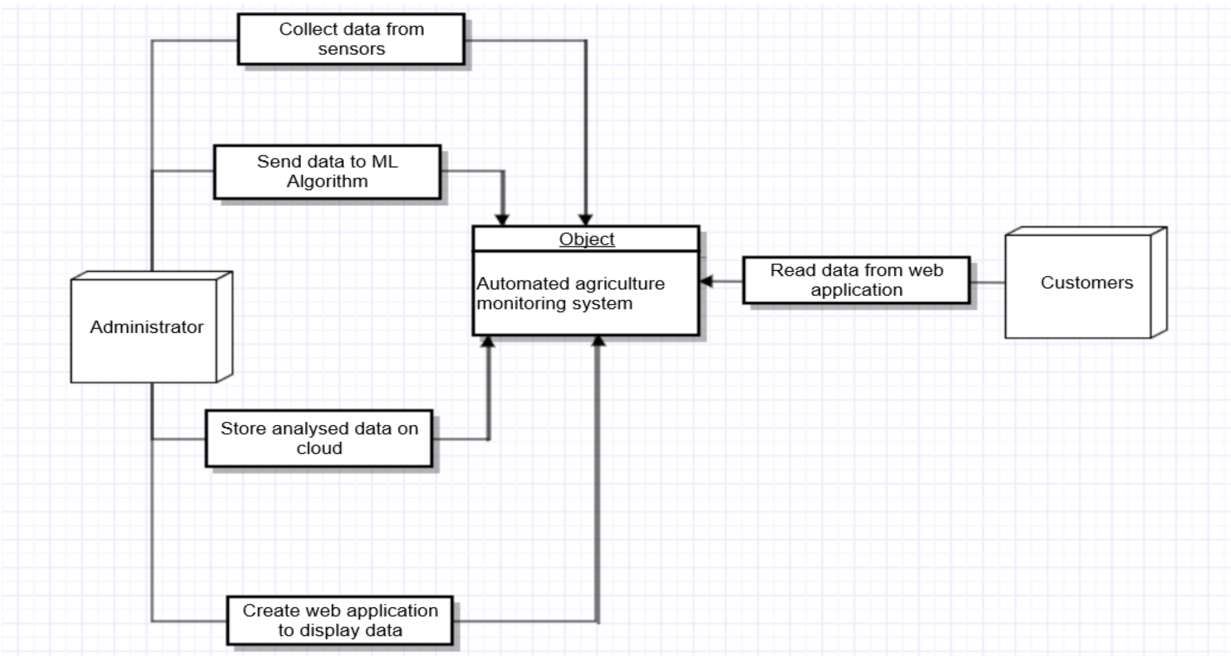

Figure 7: Context Diagram

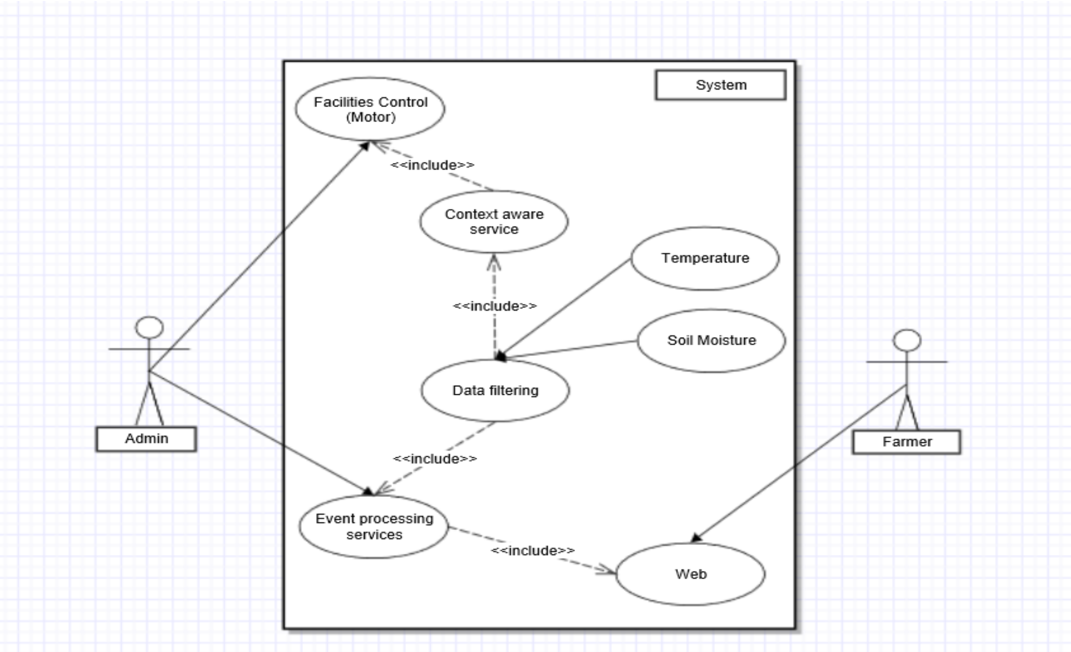

Figure 8: Use Case Diagram

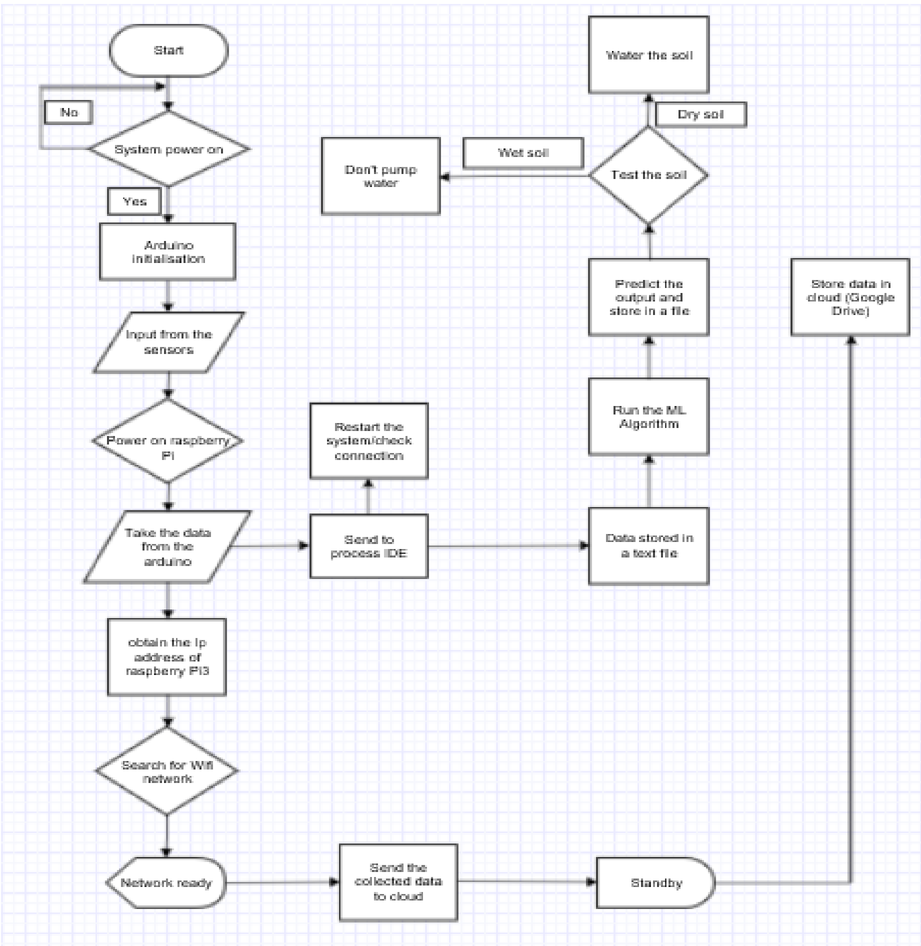

Figure 9: Flowchart of IoT Based Irrigation System

Implementation Results

The Intelligent IoT based Automated Irrigation System developed involves Arduino and Raspberry Pi3 as microcontroller and processing unit. In addition moisture and temperature Sensors deployed in soil for sensing the temperature and soil moisture level. These sensors are connected to Arduino microcontroller where sensed information sent to the microcontroller for action. In addition to these sensors, the actuator for water pump also connected to Arduino for pumping the water.

The sensed data are then communicated serially using serial communication to Raspberry Pi3 control unit where machine learning algorithm K-NN being deployed. The Pi3 control units holds the machine learning algorithm towards training the data set pertaining to moisture and temperature for different soil conditions like dry, little dry, wet, little wet and accordingly prediction done. The predicted output is sent as control signal to Arduino for actuating the pump for watering the field accordingly. Lastly the information on the field being irrigated is stored in Webpage of Cloud for farmers to access. This entire prototype is shown in Fig.10. Figure.11 shows the Raspberry Pi3 environment setup which is an Edge level processor where intelligent analysis carried out by employing K-NN Machine learning algorithm for predicting the soil condition based on captured Soil moisture and temperature data and also on the trained data sets pertaining to Soil moisture and temperature for different types of soil which are dry, little dry, wet, little wet.

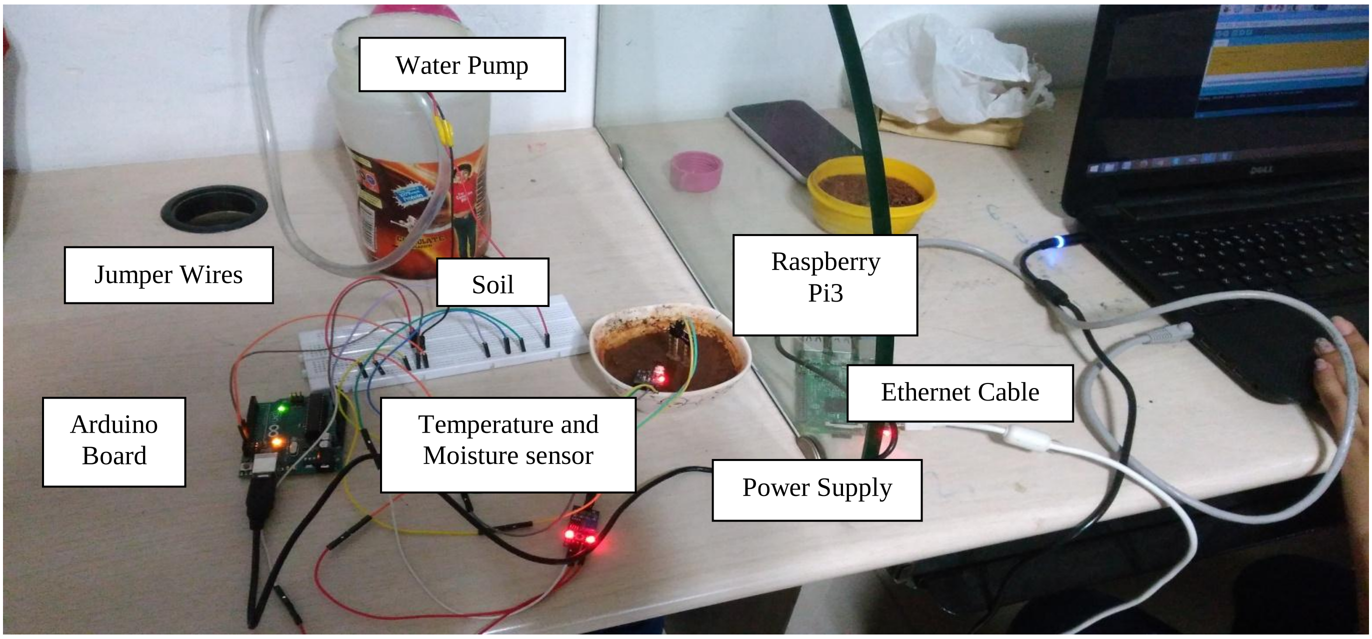

Figure 10: IoT Based Automated Irrigation System Prototype

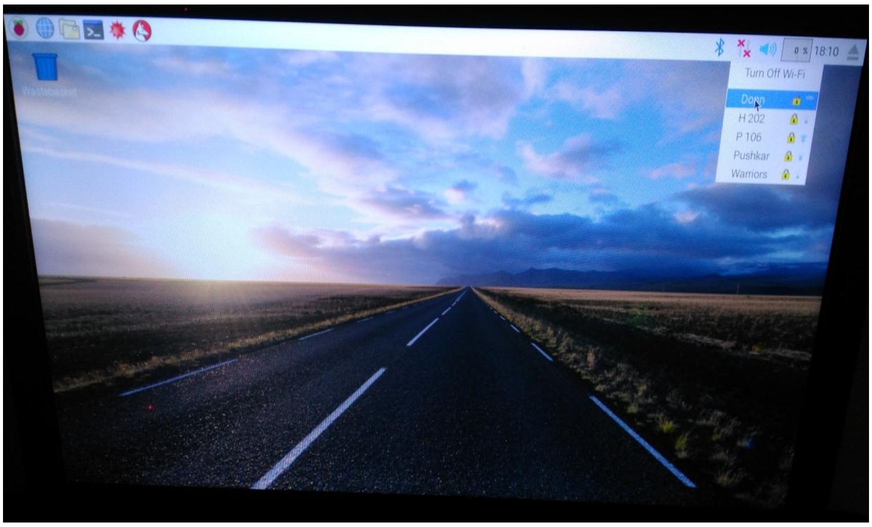

Figure 11: Raspberry Pi3 Environment

Figures 12 to 15 shows the different moisture sensor data against temperature for different types of soil – Dry, little dry, little wet and wet been captured periodically and same data been trained using machine learning algorithm K-NN. The data being trained using K-NN Machine learning algorithm been stored in.csv file. This where the intelligence comes into play where the machine learning algorithm would predict the soil condition for watering based on sensed and trained data set rather than just scheduling the irrigation perdiocially in a day without any intelligence.

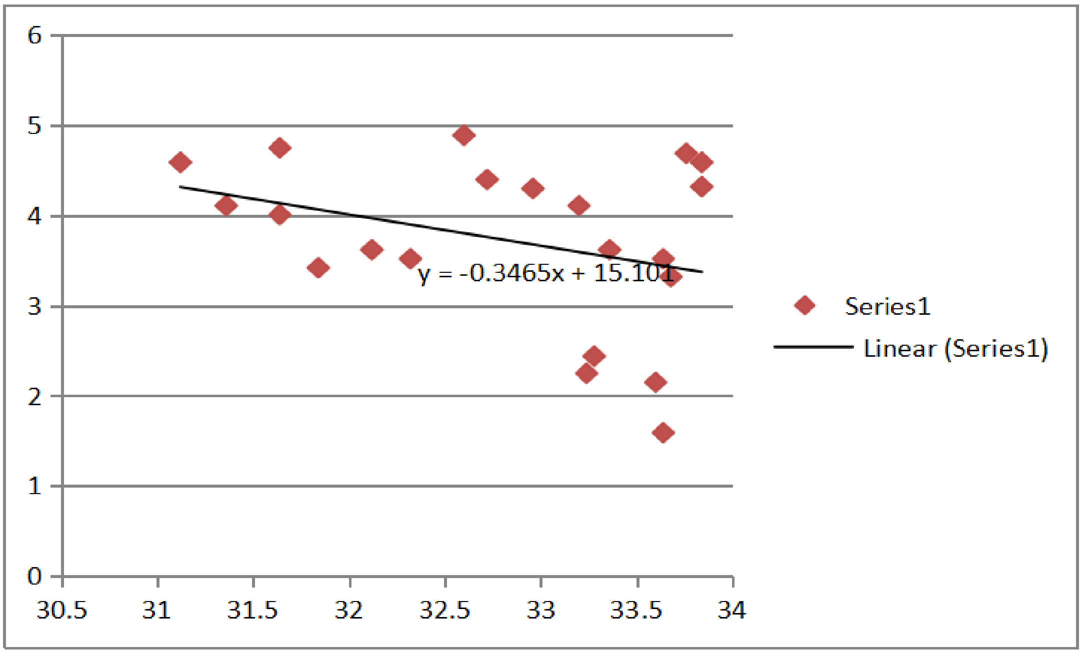

Figure 12: Graph for dry Soil

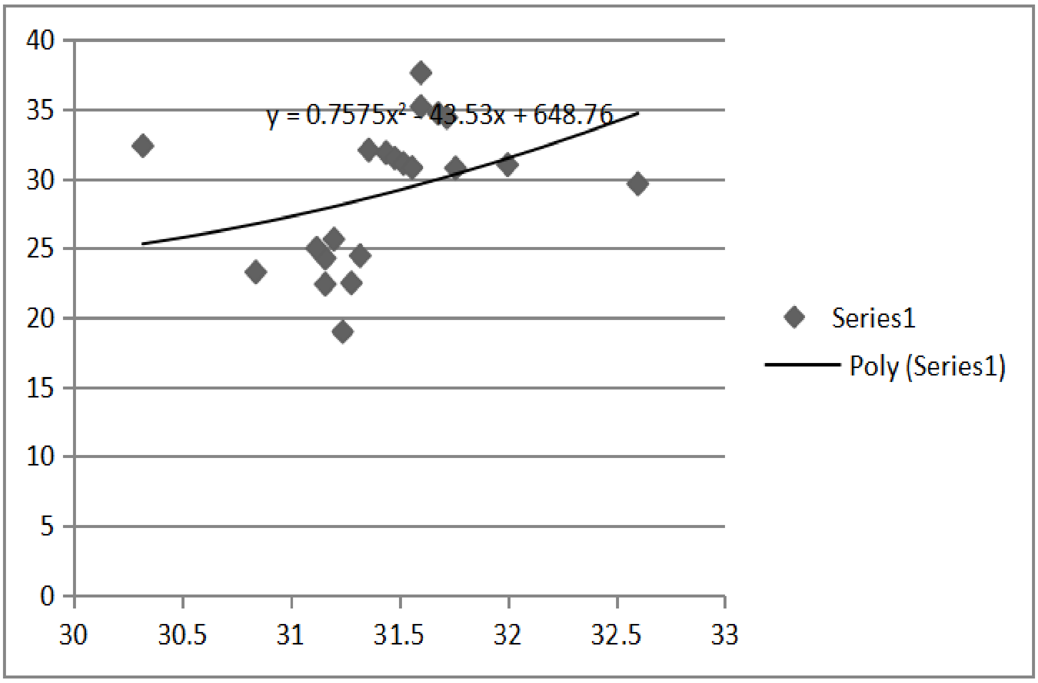

Figure 13: Graph for little dry soil

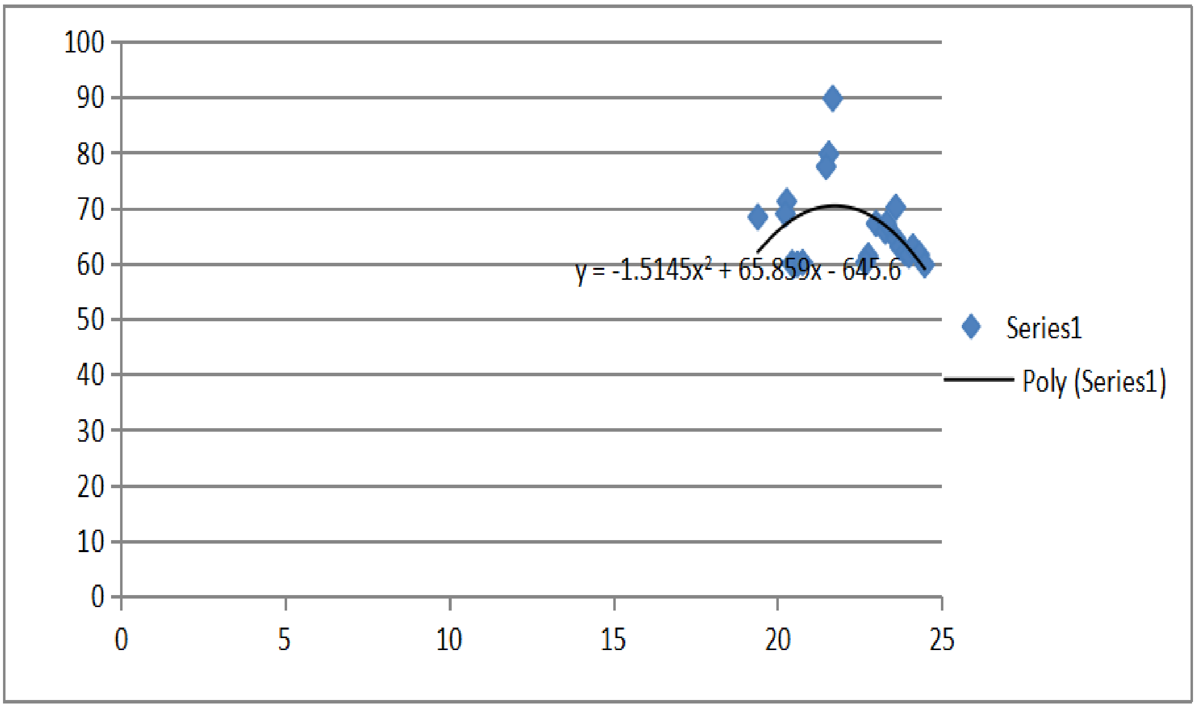

Figure 14: Graph for little wet soil

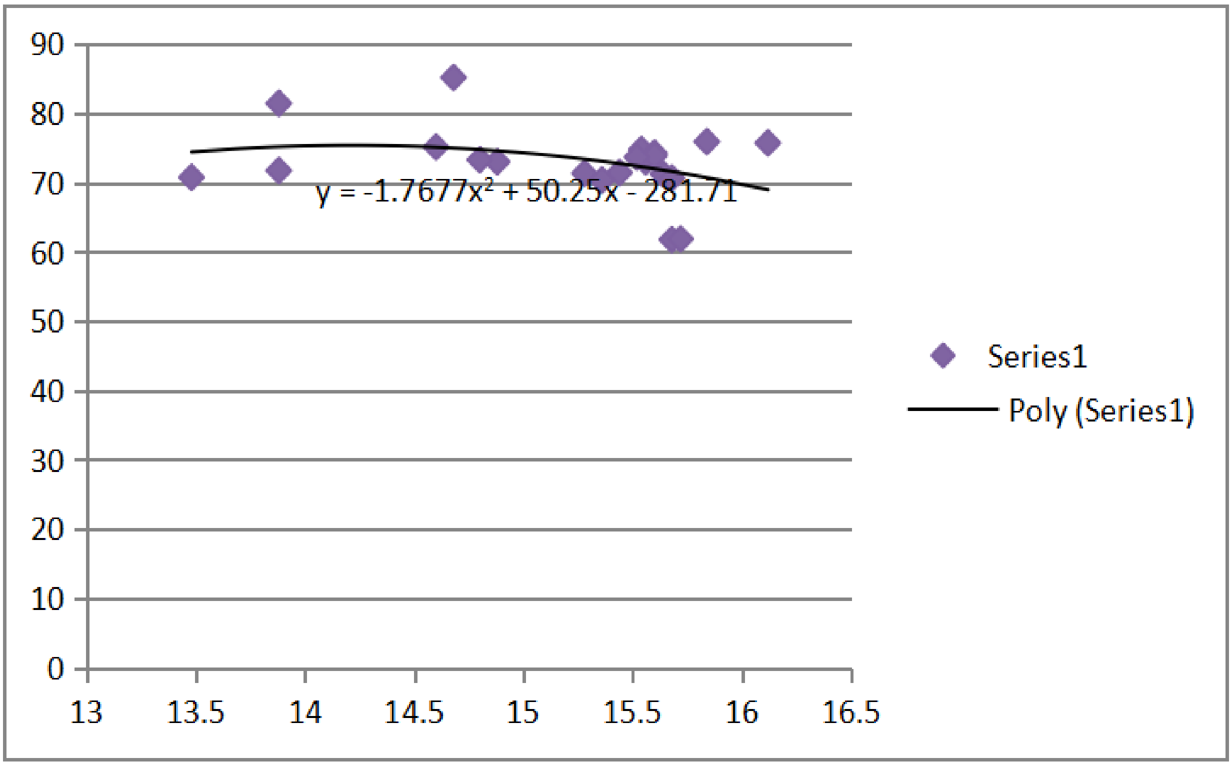

Figure 15: Graph for wet soil

Figure 16 shows the serial communication established between Arduino and Raspberry Pi3. Figures 17 and 18 shows the prediction of soil based on the input received and machine learning algorithm employed. Fig.19 shows the control signal sent to Arduino for watering the soil based on prediction output.

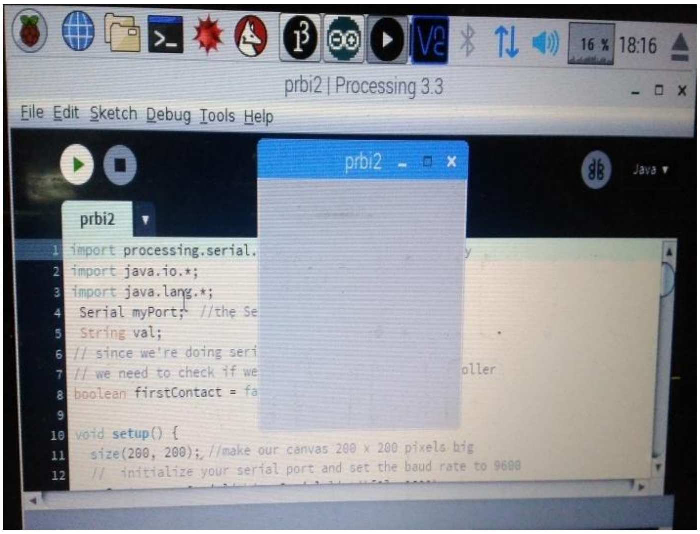

Figure 16: Serial communication between Arduino and Pi3

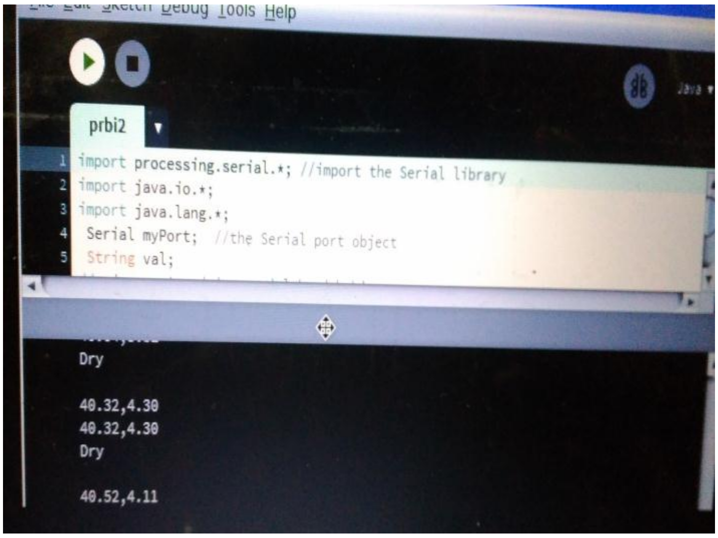

Figure 17: Process IDE – Writing Output in predict.txt

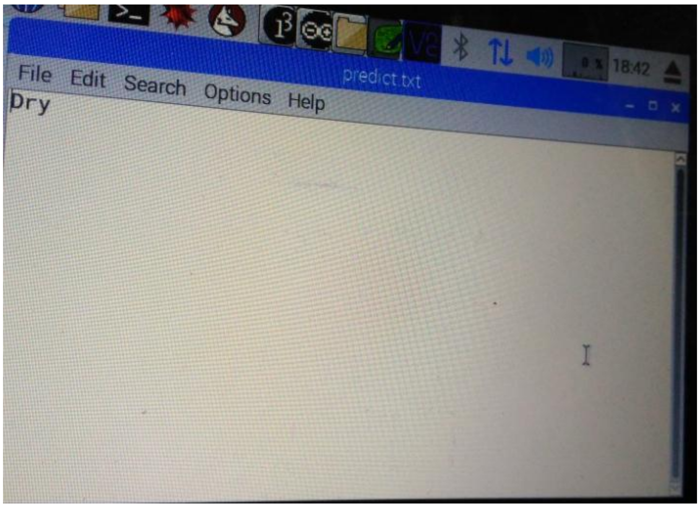

Figure 18: Storing the Predicted Output

Figure 19: Pump watering the soil

Figure 20 shows the Cloud server webpage of an Intelligent IoT based Automated Irrigation system for farmers to access. Figure 21 shows the graph data sheet of moisture versus time.

Figure 22 shows the CSV file of the trained data set for this type of soil. Fig.23 shows the Predicted output file which can be accessed by farmers mobile.

Figure 20: Cloud Server Webpage

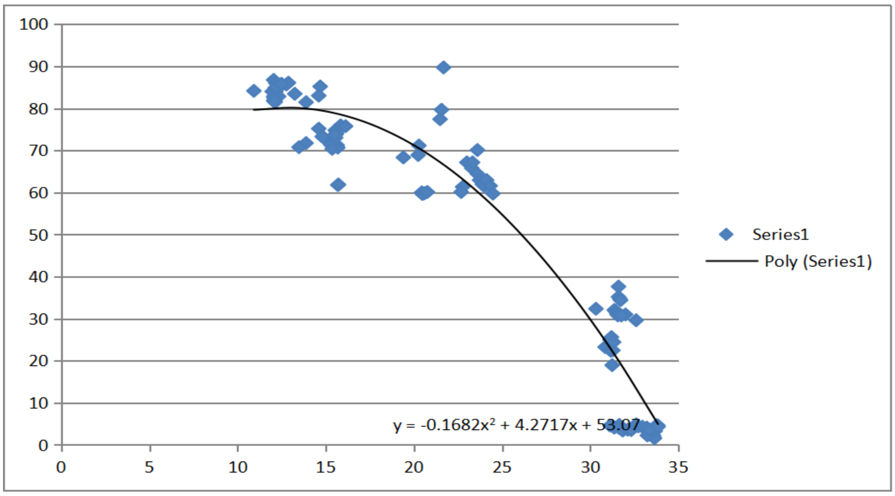

Figure 21: Graph data sheet of moisture versus temperature

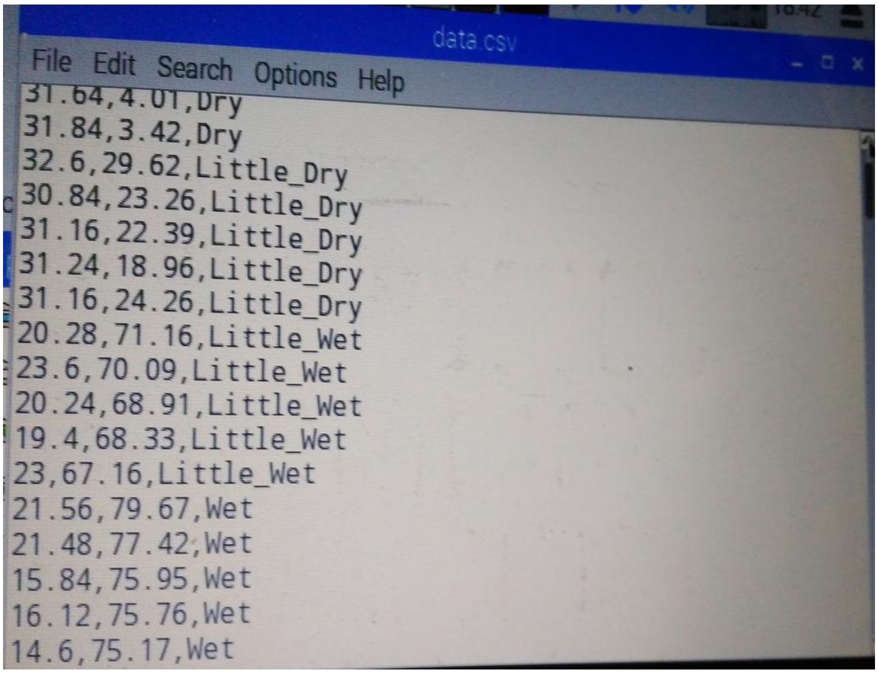

Figure 22: CSV file of the trained data set

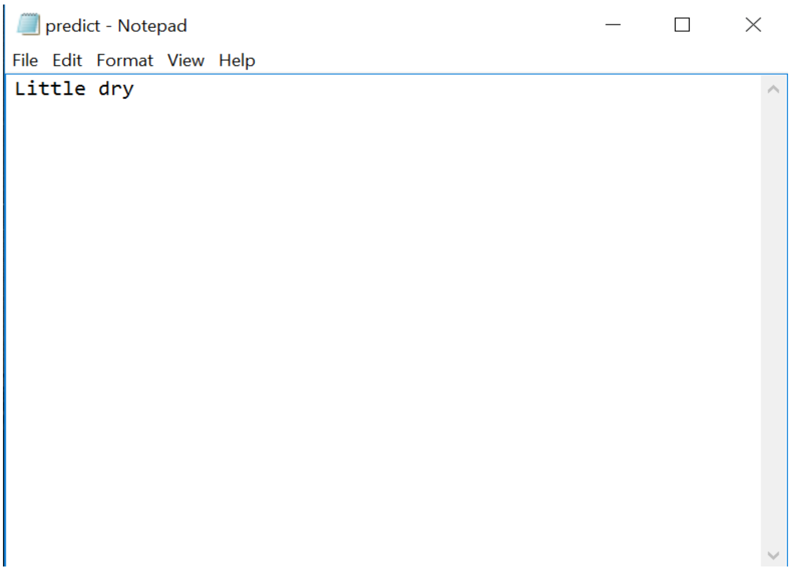

Figure 23: Predicted output file

Conclusion and Future Work

Agricultural monitoring is very much needed to reduce much of human labour and at the same time minimise on water usage. Lot of system been developed employing Wireless Sensor in monitoring and predicting the soil condition for irrigating the field. In addition machine learning techniques been employed towards crop yield and crop disease prediction only.

Now with the advent of Machine to Machine communication (M2M) which involves devices to communicate among themselves in taking action, we here have developed an Intelligent IoT based Automated Irrigation system. The system here receives the input to microcontroller where Moisture and temperature sensor connected. The sensor input is transmitted serially to Pi3 which is edge level processor where K-NN machine learning algorithm employed for predicting the soil condition based on trained data set. So accordingly the control signal sent to Arduino back again for watering the pump. The trained data set and predicted data are stored in Cloud server for farmer's access via their mobile phone. This has resulted in complete automated irrigation system employing IoT Technologies where devices communicate among themselves in predicting the soil condition for watering the field. This proves that the use of water can be diminished and hence water will not be wasted as compared to the present records. It reduces the human resources. This irrigation system was found to be feasible and cost effective for optimizing water resources for agricultural production. The irrigation system can be adjusted to a variety of specific crop needs and requires minimum maintenance. Furthermore, the Internet link allows the supervision through mobile tele- communication devices, such as a Smartphone. Besides the monetary savings in water use, the importance of the preservation of this natural resource justify the use of this kind of irrigation systems.

In Future, an Intelligent IoT based Automated Irrigation system can be extended not just for irrigating the field with water but also for deciding on spraying appropriate chemicals for proper growth of crop. The same work can be extended by looking into water level in tank before irrigating the field. Lastly the data security and integrity of agricultural data can be secured while transmitting for analysis towards prediction and sending the control signal for actuation.

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