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Intelligent Irrigation System Based on ML and IoT

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ABSTRACT

Machine Learning and Internet of Things (IoT) is making advancements in the agricultural sector for better yield quality and effective farming strategies. Due to scarcity of clean water, optimal use of water is required. Less amount of water or excess water can damage the crop. To avoid this, we are designing an Intelligent Irrigation System with the help of IoT and ML Algorithms. ML can help in improving the Irrigation System in such a way that it eradicates crop disease due to excess irrigation, increases yield, optimizes water usage, hence saving clean water. This survey paper aims to help farmers to improve their productivity and quality of crops.

Keywords-- Machine Learning, IoT, Ensemble Algorithm, Random Forest Regression, GBRT, SVR

I. INTRODUCTION

1.1 Current Scenario

The growth of a plant is dependent on the right amount of water. Irrigation systems are used for distributing water in fields . Existing modern irrigation systems cannot predict the quantity of water required by the crops. This may lead to over irrigation or under irrigation , ultimately hampering the proper development of crops.

Agricultural sector utilizes a huge quantity of water for irrigation purposes. Traditional and existing irrigation methods do not use the water optimally. Water scarcity is a major problem across the globe and it is getting worse with increasing population therefore it is necessary to efficiently use water in every sector.

Hence we need an enhanced system that can accurately predict the quantity of water needed by the crop. This can be done using ML techniques and IoT .

1.2 Smart Irrigation System

Agriculture yield can be enhanced with the help of solutions based on ML and Internet of Things. Automatic irrigation or smart irrigation systems use various latest technologies like ML, cloud computing, Internet of things sensor networks. IoT based technologies will help in connecting various application specific objects like sensors with the internet for soil moisture detection, temperature detection and will provide a significant amount of data for further processing. We can employ various machine learning techniques like random forest regression, GBRT, Linear regression, Support vector regression for future predictions of soil moisture and making smart decisions of water requirements for irrigation of crops.

II. LITERATURE SURVEY

Swetha, R. S., A.M. and M. Doraipandian , 'IoT Framework for Smart Irrigation using Machine Learning Technique'[1] has proposed an ensemble learning approach, i.e, using multiple machine learning approaches and their results are aggregated together by bootstrap aggregation to get an optimised result. The critical parameters for determining the water requirement are collected via field sensors and a weather condition report is fed into the prediction model. Water pump is automatically switched on/off based on the result of the model.

S Vijendra, A jain, A Vij, S bajaj, Aarushi sharma A bassi, 'IoT and machine learning approaches for automation of farm irrigation systems'[2] has proposed a low-cost approach towards making the irrigation system automatic. They have established a distributed system over the field. Machine Learning algorithms used were svr and random forest. To monitor the complete field they used sensor node inter-connectivity.

Deepak Sharma, Gursimran Singh, Amarendra Goap, Satish Kumar, A Shukla, Sugandha Sehgal, 'Machine Learning based soil moisture prediction for Internet of Things based Smart Irrigation System' [3] predicts the moisture of soil in the field for optimizing the irrigation water consumption using ML techniques. The result obtained by GBRT (Gradient Boosting regression Trees) is more promising than other analyzed approaches.

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T Ramesh, Akshay S, 'Efficient Machine Learning Algorithm for Smart Irrigation' [16] uses sensors for collecting the data like soil moisture, humidity, temperature using Machine learning algorithms. K-means and SVM face overfitting problems so to avoid this they used the K-nearest neighbor method. This suggested system can accomplish a fully automated irrigation system. They also explained detailed outcomes based on a 3-weeks predefined dataset using this proposed system.

D. S, A. Goap, C. Krishna, A.K. Shukla, 'An IoT based smart irrigation management system using Machine learning and open source technologies'[4] Says about smart systems based on open-source technology for prediction of irrigation requirement of fields via sensing field parameters such as environmental conditions, moisture of soil and soil temperature also with the atmospheric data from the Internet. This paper suggests an IOT based smart irrigation design with a hybrid ML (SVM and K-means clustering) based approach for predicting the moisture of soil. The algorithm uses weather forecast information /data along with sensor data to predict the moisture of soil for better accuracy and error rate.

Ting-Wei; Huang, Yu-Chuan; Huang, N-Fu, Chang. 'A Machine Learning Based Smart Irrigation System with LoRa P2P Networks'.[19] They employed a communication protocol based on LoRa for controlling the irrigation system and collecting data .Sensors in the farm forward field data to linear regression algorithms which always train itself on the data set obtained via real life farmers' irrigation data for the same crop field. The model shows water mainly dependent on air temperature and sunlight intensity. Results of experiments show that we can provide very real-time, cost-effective, and bi-directional communications for the greenhouse; integrating the L.O.R.A. P2P network with the ML model which will make it an automatic and accurate irrigation system.

Y. Sun, J. Kwok, A smart IoT-based irrigation system with automated plant recognition using deep learning [12], states that there is a diverse range of plants, and hence the amount of water required by the plants' species is also different. To solve this issue, they have designed an irrigation system using deep learning that can adjust the volumes of water for every plant using the plant recognition system. Software and hardware are 2 important components of the solution. The software is connected with cameras for plant recognition, and it predicts the amount of water required using a database; the hardware components control the amount of water that can flow out. Soil moisture meters and Arduino are used to regularly update the irrigation system and this aids regulation of the irrigation system based on the weather.

A. Meitin, Goldstein, A., L. Fink, O. Lutenberg et al. and S. Bohadana , 'Applying machine learning on sensor data for irrigation recommendations: Revealing the agronomist tacit knowledge ' [10]. The focus of this study was to create a system that understands the irrigation planning process of farmers and then make the predictions for their irrigation recommendations. This purpose was accomplished by implementing Machine learning on a dataset that combined data from multiple sources. As per the results, non-parametric models, specifically the BTC model & GBRT model, predicted irrigation decisions more accurately than linear regression models with success rates of 95% and 93%, respectively. Even if BTC is performing slightly better than GBRT. They recommend using GBRT in irrigation-based applications because it provides more accurate results.

Comparison Table

Sr. No	Paper	Algorithm Used	Metric Used	Result
1.	Swetha, Ramya, S., A.M. and M. Doraipandian , 'IoT Framework for Smart Irrigation using Machine Learning Technique'	Bootstrap aggregation	Accuracy	97%
2.	Singh vijendra, abhishek jain, Anneketh Vij, shivam bajaj, Aarushi sharma, Aashima bassi, 'IoT and machine learning approaches for automation of farm irrigation system'	SVR, random forest regression	Accuracy	81.6%
3.	Deepak Sharma, Gursimran Singh, Amarendra Goap, Satish Kumar, A K	Gradient Boosting regression Trees	Accuracy	94%

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	Shukla, Sugandha Sehgal, 'Machine Learning based soil moisture prediction for Internet of Things based Smart Irrigation System'			
4.	T K Ramesh, Akshay S, 'Efficient Machine Learning Algorithm for Smart Irrigation'	K-nearest neighbour method	Accuracy	9 3%
5.	D. S, A. Goap, C. Krishna, A.K. Shukla, 'An IoT based smart irrigation management system using Machine learning and open source technologies'	SVM and K-means clustering	Accuracy	96%
6.	Ting-Wei; Huang, Yu-Chuan; Huang, N-F, Chang. 'A Machine Learning Based Smart Irrigation System with LoRa P2P Networks'	Linear regression	Accuracy	52.3%
7.	Y. Sun, J. Kwok, A smart IoT-based irrigation system with automated plant recognition using deep learning	Deep Learning	Accuracy	99.35 %
8.	A. Meitin, Goldstein, A., L. Fink, O. Lutenberg et al. and S. Bohadana ,'Applying machine learning on sensor data for irrigation recommendations: Revealing the agronomist tacit knowledge '	Gradient Boosting Regression Trees and Boosted Tree Classifier	Accuracy	92.7% and 95%

III. MACHINE LEARNING TECHNIQUES CURRENTLY IN-USE FOR SMART IRRIGATION

ML algorithms train themselves from the data provided and predict the result using data. Supervised learning algorithm are Regression and classification, Clustering is an unsupervised algorithm. Regression & classification models can be used to predict usage of water according to the requirements of the crops. **Figure 1** shows different machine learning techniques currently in use or proposed for irrigation application for prediction purposes.

Random Forest Regression

The Random Forest algorithm uses the concept of supervised machine learning techniques. It is a 'Tree' based algorithm. The forest which the algorithm builds is an ensetrees trained with a bagging method. Hence it is known as 'Random Forest'.

Random Forest creates multiple decision trees and then merges them together to get more accurate and stable predictions. Decision trees cause overfitting. This problem has been solved by using Random Forest in place of the Decision tree. Classification and regression both can be achieved by it. Random forest has the same amount of hyperparameters as a decision tree. Hyperparameters help to optimize the predictive ability of a model and make the model faster.

Gonzalez *et al*[20] has compared CART (Classification and Regression Tree), Bootstrap & Random forest for forecasting of electricity prices and has concluded that Random Forest is best among them.

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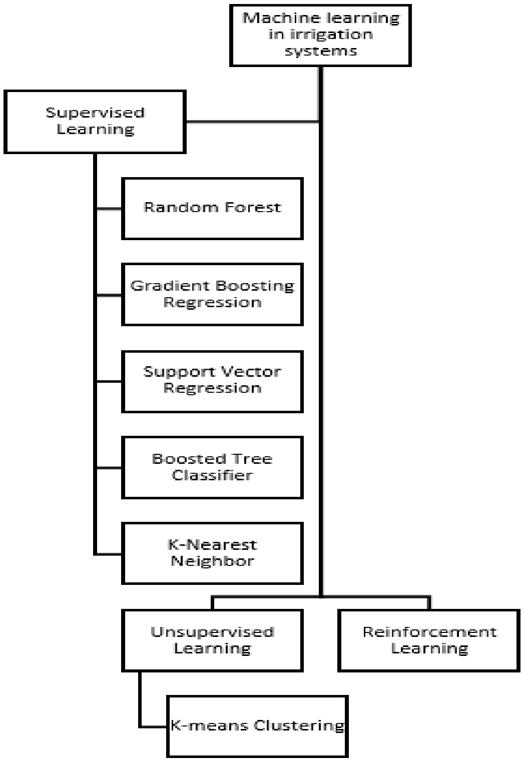

Figure 1: Different machine learning techniques used for irrigation purposes.

Gradient Boosting Regression Trees (GBRT)

GBRT is a statistical, non-parametric and fixed technique which is used for classification problems and problems of regression. Predictive models are generated as an ensemble of weakly predicted models. By optimizing the differentiable loss function, a stepwise model is built and generalized. Gradient boosting (GB) helps you build additive models step by step. The regression tree fits the non-positive gradient of the loss function specified in each repetition. Every new model tries to rectify the error in the former tree.

The trees are connected in series and every tree attempts to minimize the error of the former tree. Due to this consecutive connection, boosting algorithms are slow to learn, however, they are highly accurate. Slow-learning models work powerfully in statistical learning. Weak learners are adjusted so that new learners fit into the residuals of the last model. The resulting model is collection of the results of each step, resulting in a good learner. The residuals of the current model correspond to added decision tree.

Support Vector Regression (SVR)

In Linear Regression, all points are considered for calculating the error so as to find the best fit line(green line), whereas in Support Vector Regression, only those points within the decision boundary line will be considered for calculating the error so as to find the best fit line. Maximum number of points lie on the hyperplane which will be the best fit line.The decision limit is at the distance "a" from the original hyperplane, so the data point or support vector closest to the hyperplane is within this boundary.

Therefore, only the points with the lowest error rate within the decision limits or within the tolerance limits are retrieved. This will give you a better model.

K-Means Clustering

K-means : K localised averages of whole scattered data.

The goal of Kmethod is simple. It's about organizing similar data points and discovering the underlying patterns.

To fulfil this goal, Kmeans looks for a specified number (k) of clusters (a collection of data points aggregated together) in the dataset.

Defines the number of targets k associated with the number of centroids (represent the midpoint of the cluster) required for dataset.

Each data point is mapped to each cluster by decreasing the total of the squares of the clusters.

Learning begins with the foremost group of arbitrarily chosen centroids. It is used as the initial point for each cluster and then does repetitive calculations to optimize the position of centroids.

The process of optimizing the centroids stops if

1. Optimized positions for centroids are achieved, i.e. there is no change in the centroid position further.
2. The number of iterations planned for the optimization loop has been achieved

IV. PROPOSED SYSTEM

This proposed system aims to provide effective management of agricultural farms by using limited resources. By incorporating IoT and Machine Learning techniques, smart irrigation can be developed for effective and minimal usage of water.

4.1 Parameters for Prediction

Goap A. *et al* [4] had developed a web service using python which collects Weather forecast data such as temperature,cloud cover humidity, precipitation and UV index. The soil moisture difference is the difference between minimum moisture of the soil of the previous day and the minimum moisture of soil on that day. Ramya, S. *et al* [1], Zhao *et al*[6] and Yang et al [7] state that evapotranspiration rate is an important element which decides the water consumption in an agricultural field, which is calculated based on a weather forecasting report.
Anneketh Vij *et al* [2] uses DHT11 (Digital Humidity and Temperature) for measuring humidity and temperature.The

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collective study of (SVR)Support vector regression, multiple linear regression and random forest regression was carried out for predicting soil moisture.

4.2 Evapotranspiration

Evapotranspiration rate is the rate of water evaporating from the crop. It can be calculated based on the temperature and extraterrestrial radiation. The evapotranspiration (ETj) of the crop is calculated based on a weather forecast report using the Reduced-set Penman Montieth model[6][7].

$$ET = 0.0023(Temp_j + 17.8)\sqrt{Tmax - Tmin} \times R_a$$

Where,

T_{max} = Maximum Temperature

T_{min}= Minimum Temperature

$Temp_j$ = Average of the minimum and maximum temperature

R_a = Extraterrestrial radiation.

$$R_a = \frac{SRj}{K \times \sqrt{Tmax - Tmin}}$$

Zhao *et al.*[6] had stated that estimation of soil moisture for crops is dependent on evapotranspiration. Goldstein *et al.* [10] stated that water requirements for agricultural fields are mainly contributed by evapotranspiration and are a significant parameter for automatic Irrigation Scheduling.

Methodology

The system is divided into four sections: Field sensor data acquisition, ML based soil moisture prediction, web based weather data collection, responsive interface-monitoring and controlling unit. **Figure. 2** depicts the system architecture of the proposed model.

Field Sensor Data Acquisition:

Agricultural land is divided into different sections and a sensor is deployed randomly in the sections to cover the entire area. An assembly of 4 sensors and a gate-way node forms the Sensor node. The data from the field is collected from the 4 sensors that are deployed, they are -

- DHT11 relative humidity sensor.
- DS18B20, 9-bit digital thermometer.
- GUVA-S12SD, UV sensor.
- VH400 soil moisture sensor.

These sensors will be connected to an ESP-32 microcontroller with integrated wifi.

The ESP32 microcontroller collects data from sensors and sends it to a gateway node which is a Raspberry Pi B+ Board. Multiple ESP32 microcontrollers will be connected to the gateway node(Raspberry Pi) of respective regions. They will be connected via M.Q.T.T. (Message Queuing Telemetry Transport) communication protocol.

M.Q.T.T. is a protocol based on the publish-subscribe method which is used for one to many communications. ESP32 will act as publisher, which will publish the data collected from sensors to the subscriber, which is a Raspberry Pi board of respective regions. The broker acts as an intermediary which delivers a message from the publisher to respective subscribers. Ramya S *et al*.[1] have used CloudMQTT services for data exchange.

Ml Based Soil Moisture Prediction

Field data combined with meteorological data is used to predict soil moisture through svr models and Kmeans-clustering algorithms. Algorithm provides soil moisture for several days and also provides water demand for irrigation established on the predicted moisture of soil.

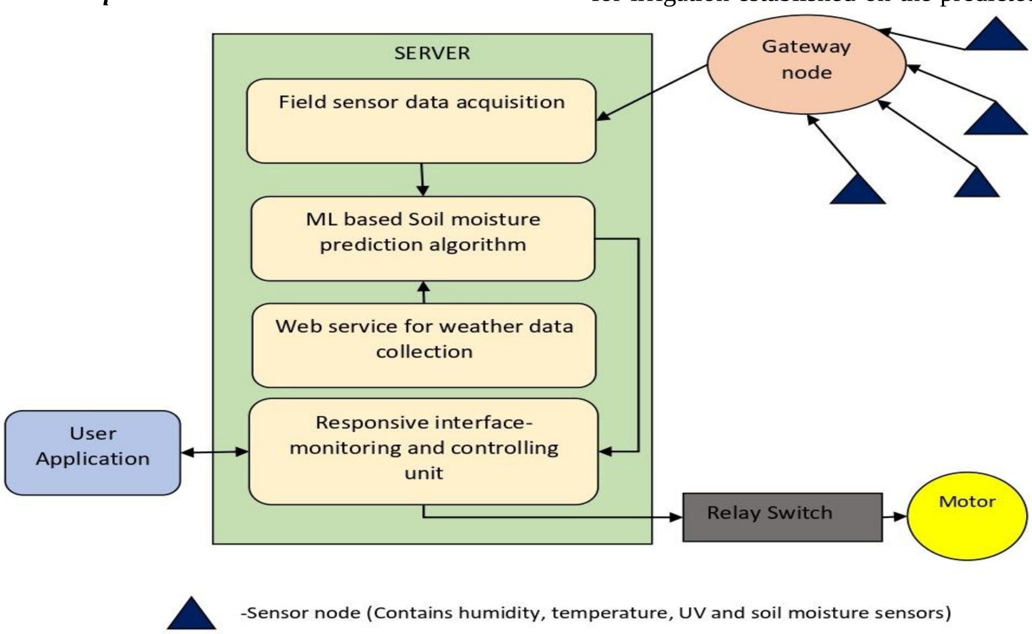

Figure 2: Architecture of proposed system

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Support Vector Regression (SVR)

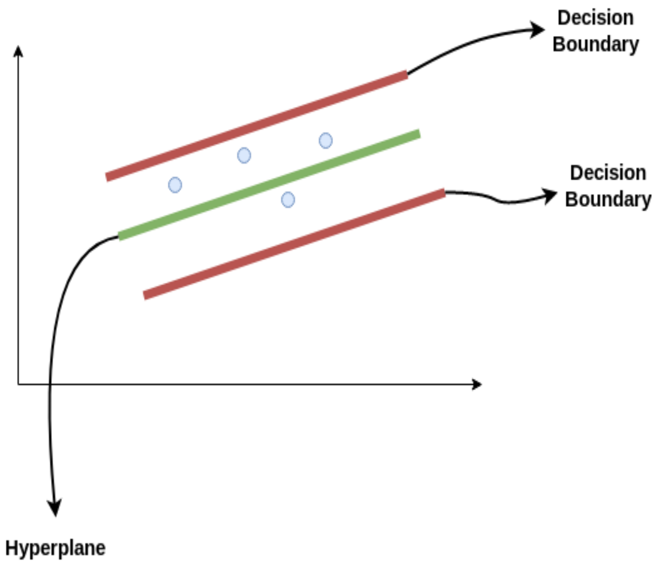

Figure 3

In Linear Regression, all points are considered for calculating the error so as to find the best fit line(green line), whereas in Support Vector Regression, points in the decision border line will be considered for calculating the error so as to find the perfect fit line. Greatest number of points lie on the hyperplane which will be the best fit line. The decision border lies at 'm' distance from the actual hyperplane in a way that the nearest point to the hyperplane and support vector are in the boundary line.
So only those points are taken which belong in the decision boundary, in the margin of tolerance and have the lowest error. The model obtained through this is a perfect fit model.

K-Means Clustering

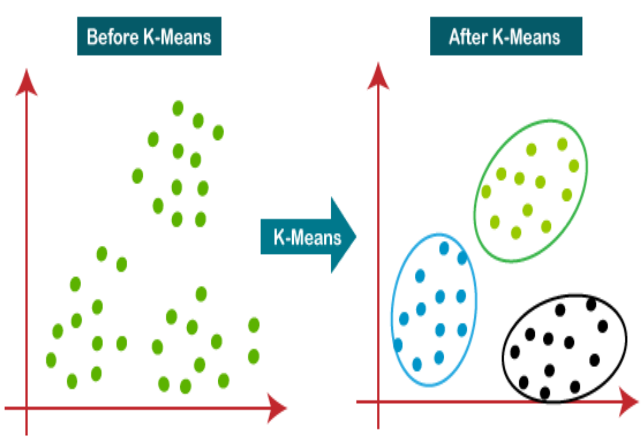

Figure 4

K-means: K localised averages of whole scattered data.

The goal of the K-method is simple: organization of alike points of data and finding out patterns which are underlined.

To accomplish the objective, K-means fixes the number of clusters(data points collected together) in a dataset.

We need to define the amount of centroids required present in dataset.

In-cluster sum of squares is reduced to assign data points to each cluster.

Foremost groups of chosen centroids are used as the initial point for each cluster. Repetitive calculations are done to optimise the place of the centroids.

Web Based Weather Data Collection

Weather data will be collected daily from the farm which includes minimum temperature, maximum temperature, humidity, soil moisture and UV. Using this weather data evapotranspiration rate will be calculated using Penmann-Montieth formula. Evapotranspiration plays a crucial role in deciding the usage of water in farms.

Responsive Interface-Monitoring and Controlling Unit

For monitoring, we will develop a web-based interface using the python web framework. Minimum and maximum threshold values can be set by the user. After the prediction of required soil moisture by the prediction algorithm, the data is sent to the controlling unit. The control unit can be set to manual control or auto control. In manual control the user can turn the motor On/Off manually. Whereas, in auto control mode, based on predicted soil moisture, the interface will automatically instruct the model to start or stop the motor via a relay switch depending on the threshold moisture level required by the crop.

V. ALGORITHM

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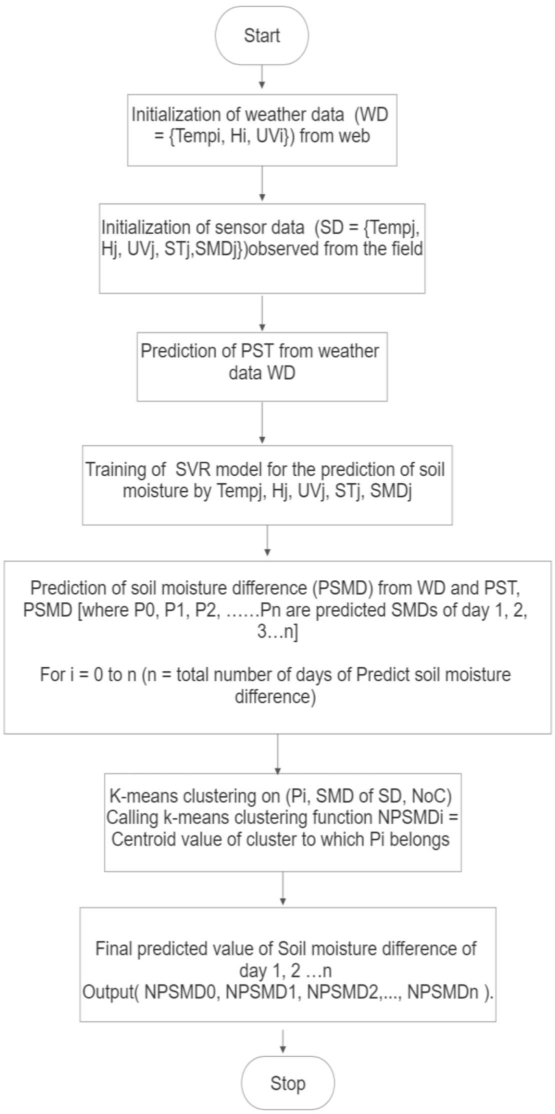
Soil Moisture Prediction



Pump Control

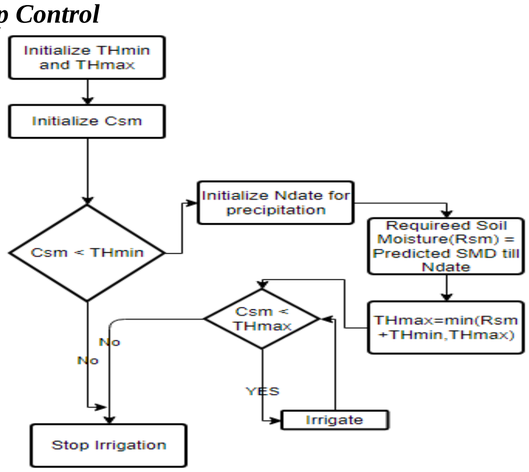


Figure 5: Flow chart of pump control

Important Abbreviations

Variable name	Variable description
WD	Weather Data
H	Humidity
UV	Ultraviolet
SD	Sensor Data
ST	Soil Temperature
SVR	Support Vector Regression
PST	Present Soil Temperature
PSMD	Predicted Soil Moisture Difference
NPSMD	New Predicted Soil Moisture Difference
CSM	Current Soil moisture
RSM	Required Soil moisture
Ndate	Nearest date of precipitation
TH(min)	Minimum Threshold soil moisture
TH(max)	Maximum threshold soil moisture

VI. CONCLUSION

Advanced techniques like AI, IoT and ML can help in solving problems in the agricultural sector. Smart irrigation systems based on IoT and ML can help in optimally using the water for agriculture. This will save water and increase the quality and quantity of crops. This paper reviews the existing smart irrigation methods and the machine learning techniques used for predicting irrigation volumes required by the crops and this survey identifies the best system for smart irrigation. SVR and K-means clustering are promising ML techniques for predictions and accurate decisions. Due to this model it will be possible to decrease the manual work and increase the efficiency of work.

REFERENCES

[1] Ramya, S., Swetha, A.M., & M. Doraipandian. (2020). IoT framework for smart irrigation using machine learning technique. *Journal of Computer Science*. DOI: 10.3844/jcssp.2020.355.363.
[2] Anneketh vij, singh vijendra, abhishek jain, shivam bajaj, aashima bassi, & Aarushi sharma. (2020). Iot and machine learning approaches for automation of farm

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https://doi.org/10.31033/ijemr.11.6.6

irrigation system .*Procedia Computer Science*. DOI: 10.1016/j.procs.2020.03.440.

[3] Gursimran Singh, Deepak Sharma, Amarendra Goap, Sugandha Sehgal, A K Shukla, & Satish Kumar. (2019). Machine learning based soil moisture prediction for Internet of Things based Smart Irrigation System. *IEEE*. DOI: 10.1109/ISPCC48220.2019.8988313.

[4] Goap, A., Sharma, D., Shukla, A. K., & Rama Krishna, C. (2018). An IoT based smart irrigation management system using Machine learning and open source technologies. *Computers and Electronics in Agriculture, 155, 41–49.* DOI: 10.1016/j.compag.2018.09.040.

[5] K. Chaudhary. (2020). Prediction of crop yield using machine learning. *International Journal of Engineering Applied Sciences and Technology*.

[6] Zhao, T., Q.J. Wang, A. Schepen, & M. Griffiths. (2019). Ensemble forecasting of monthly and seasonal reference crop evapotranspiration based on global climate model outputs. *Agric. Forest Meteorol., 264*, 114-124. DOI: 10.1016/j.agrformet.2018.10.001.

[7] Yanga, Y., Y. Cui, K. Baic, T. Luo, & J. Dai et al. (2019). Short-term forecasting of daily reference evapotranspiration using the reduced-set Penman-Monteith model and public weather forecasts. *Agric. Water Manage. 211*, 70-80. DOI: 10.1016/j.agwat.2018.09.036.

[8] Y. Mahajan, M. Pachpande, R. Sonje, S. Yelapure, & M. Navale. (2018). Effective use of water in irrigation system using machine learning. *International Journal of Current Research.* DOI: 10.3844/jcssp.2020.355.363.

[9] Catolino, G. & F. Ferrucci. (2018). An extensive evaluation of ensemble techniques for software change prediction. *Proceedings of the IEEE Workshop on Machine Learning Techniques for Software Quality Evaluation*, pp. 25-30. DOI: 10.1002/smr.2156.

[10] Goldstein, A., L. Fink, A. Meitin, S. Bohadana, & O. Lutenberg et al. (2017). Applying machine learning on sensor data for irrigation recommendations: Revealing the agronomist tacit knowledge .*Int. J. Adv. Precis. Agric., 19*, 421-444. DOI: 10.1007/s11119-017-9527-4.

[11] M.A. Zamora-Izquierdo, J. Santa, J.A. Martínez, V. Martínez, & A.F. Skarmeta. (2019). Smart farming IoT platform based on edge and cloud computing .*Biosyst. Eng. 177*, 4–17. DOI: 10.1016/j.biosystemseng.2018.10.014.

[12] J. Kwok & Y. Sun. (2018). A smart IoT-based irrigation system with automated plant recognition using deep learning. *ACM Int. Conf. Proceeding Ser.* DOI: 10.1145/3177457.3177506.

[13] S. Darshna, T. Sangavi, Sheena Mohan, A.Soundharya, & Sukanya Desikan. (2015). Smart irrigation system. *IOSR Journal of Electronics and Communication Engineering.* DOI: 10.9790/2834-10323236.

[14] Kasara Sai Pratyush Reddy, Y Mohana Roopa, Kovvada Rajeev L N, & Narra Sai Nandan. (2020). IoT based Smart Agriculture using Machine Learning. *IEEE.* DOI: 10.1109/ICIRCA48905.2020.9183373.

[15] J.Karpagam, I.Infranta Merlin, P .Bavithra, & J. Kousalya. (2020). Smart irrigation system using IoT. *IEEE.* DOI: 10.1109/ICACCS48705.2020.9074201.

[16] Akshay S & T K Ramesh. (2020). Efficient machine learning algorithm for smart irrigation. *IEEE*. DOI: 10.1109/ICCSP48568.2020.9182215.

[17] Janani M & Jebakumar R. (2019). A study on smart irrigation using machine learning. *Cell & Cellular Life Sciences Journal*. DOI: 10.23880/cclsj-16000141.

[18] A. H. Blasi, M. A. Abbadi, & R. Al-Huweimel. (2021). Machine learning approach for an automatic irrigation system in southern Jordan valley. *Eng. Technol. Appl. Sci. Res.*, *11*(1), 6609–6613. DOI:10.48084/etasr.3944.

[19] Chang, Yu-Chuan, Huang, Ting-Wei, & Huang, Nen-Fu. (2019). A machine learning based smart irrigation system with LoRa P2P networks. *IEEE 20th Asia-Pacific Network Operations and Management Symposium (APNOMS) - Matsue, Japan*.
DOI: 10.23919/APNOMS.2019.8893034.

[20] González, C., Juárez, I., & Mira-McWilliams, J. (2015). Important variable assessment and electricity price forecasting based on regression tree models: classification and regression trees, Bagging and Random Forests. *IET Generation, Transmission & Distribution*, *9*(11), 1120–1128. DOI:10.1049/iet-gtd.2014.0655.

[21] Revanth Kondaveti, Akash Reddy, & Supreet Palabtla. (2019). Smart irrigation system using machine learning and IOT. *International Conference on Vision Towards Emerging Trends in Communication and Networking*. DOI: 10.1109/ViTECoN.2019.8899433.

[22] Ashutosh Bhoi, Rajendra Prasad Nayak, Sourav Kumar Bhoi, Srinivas Sethi, Sanjaya Kumar Panda, Kshira Sagar Sahoo, & Anand Nayyar. (2021). IoT-IIRS: Internet of Things based intelligent-irrigation recommendation system using machine learning approach for efficient water usage. *PeerJ Computer Science*. DOI: 10.7717/peerj-cs.578.