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Machine Learning Based Approach for Crop Growth Monitoring in Hydroponics Cultivation

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Abstract: As the population of world's increases by the day, there is currently a challenge with how to fulfil everyone's food requirements. The development of crop growth required more time and water in traditional farming techniques. In agricultural farming, irrigation wastes a lot of water, and the supply of water for farming is dependent on rainfall. In our study, we employed hydroponic farming methods, which allow a crop to be grown in water rather than soil. We provide the essential nutrients required for plant through water so plant absorbed required nutrients from water. Today's requirement is to save the water as the day by day the climate change and unpredictable rain, so in future we have to face the problems of water shortage. Artificial intelligence and machine learning techniques is used to monitor the crop growth in hydroponic environment. Our system automatically controlled itself by retrieving sensor values and taking the necessary actions. In hydroponics system, we can reuse water so that 70% of water we can save than the traditional farming. In our research, we find the accuracy of crop growth using machine learning techniques. In our research found that Support Vector Regression and Lasso has best result on (Coefficient of DeterminationR2=0.93), Support Vector Regression (SVR) have good results on (Mean Absolute Error =12.65 and Root Mean Square Error = 21.31) and Lasso Regression (LR) have good result on (Mean Square Error=4.51).

Keywords: *Hydroponics System, Machine Learning, Internet of Things.*

1. Introduction

The expected grow of population of world is 6.7 billion to 9.2 billion in between 2007 and 2050[1]. In india the expected grow of population in urban area is 404 million upto 2050. Any nation's economy is dependent on its agricultural development. It will be highly challenging to meet the demand for food in the future due to population growth, rising food demand, and declining land availability. Climate change, unpredicted rainfall, and increased industrialization are additional factors that have an impact on the agriculture economy. In India, the majority of farmers rely on rain to help their fields grow. Farm fields need high-quality soil and the right quantity of minerals to grow properly. Farmers must contend with issues like high operating costs, high labor costs, limited farming land, and scarce water supplies [2]. Because of all these issues in the agricultural sector, enclosed farming or indoor farming techniques like hydroponics or aeroponics are absolutely important. [3].

In hydroponics the plant can be grown in water solution without soil. In Hydroponics provided necessary nutrients which require to growth of plant from water [4]. We can externally provide nutrients like calcium sulphate, magnesium, NPK and micronutrients through water in proper ratio. In this work we had developed hydroponics system with internet of technology (IOT). Now days the application IOT in every sector is available. IOT is used to transfer the data from one location to another through internet. The used of IOT allows for controlling, communicating and monitoring in real-time by used of internet network [5]. In hydroponics the goal of IOT is to gathered a real time data from sensors and to store on cloud.

Technology like artificial intelligence, machine learning, and deep learning is utilised in hydroponics to track plant growth. The application of ML algorithms helps farmers with issues like crop disease prediction, crop selection, weather forecasting, and yield prediction, however ML won't address every issue that has arisen in the field of agriculture [6]. After being trained for a particular task, ML increases the capacity of computers to perform certain tasks. Humans are able to base their decisions on their experiences, allowing machines to first learn to think like humans. There are numerous uses for ML in hydroponics, including monitoring nutrient levels, regulating crop development, and measuring the electrical conductivity of solutions [7].

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2. Literature Survey

In [8] created the AI-SHES real-time hydroponics system for monitoring and regulating real-time data. This method uses a deep neural network (DNCCN) to find the accuracy in predicting the nutrient content in the tank and identifying plant diseases. The work is carried out in three phases: hardware environment implementation, deep neural network application, and an android-based mobile application to regulate sensor data.

In[9] Build a smart greenhouse system that uses supervised machine learning to control multiple parameters, including CO2, temperature, soil moisture, humidity, and light intensity. This proposed system has four component sensor, edge, fog and cloud. This system effectively controls CO2, humidity, soil moisture, and temperature using IoT and MQTT on a network.

In [10] proposed hydroponics system in which various sensors are used such as DS18B20 sensor, DHT 11 sensor, pH Sensor. All parameter values are gathered from sensors and stored in text files, which are then converted into csv files for use with various machine learning algorithms. Text files are also sent to the thing speak server for cloud-based data aggregation, visualization, and analysis.

In [11] proposed fog computing concept over cloud for the environmental monitoring platform. In this paper developed IoT based hydroponics garden for monitoring water quality embedded with a fog model using microcontroller ESP8266. The system work with three steps, in first step fuzzy logic is used to check water quality on the basis of current reading. In second step support vector machine learning algorithm used to check short term water quality monitoring on the basis of history of locally stored reading data and third used LSTM (Long Short-Term Memory) ML algorithm for prediction of water quality parameters. The fog test work according to the performance and functionality of microcontroller.

In [12] developed a smart IoT-based low cost hydroponics system called iPONICS for controlling and monitoring greenhouses. This system uses three types of sensor nodes, master node, slave node and security node. Master nodes are the main node for controlling and monitoring water quality and transfer the data from slave node. Second slave node is used to monitor ambient condition in greenhouse and third security node monitors all movement of area. Overall system manages the water quality, temperature, humidity in greenhouse hydroponics system. Plant irrigation duration is determined by fuzzy engine.

In [13] proposed leafy green machine hydroponics system using deep learning methods. Numerous system characteristics, including air flow, carbon dioxide, moisture, and nutrient levels, can be tracked, managed, and controlled using deep learning (DNN) techniques. IoT (Internet of Things) sensors and UAVs were employed to gather all the system parameters. The high quality of yield production is provided by deep learning applications.

3. Methods and Materials Used

3.1. Experimental Setup

We developed hydroponics system using Nutrients Film Techniques (NFT) to capture the real time data to monitor the crop growth. In our research we consider spinach plant for case study, from water tank we change water with nutrients after every three days and continuously distribute the nutrients via channel to the plant's roots. We used outdoor farming, and the structure was built on a 10-by-8-sq. ft. balcony. We used PVC pipe, elbows, rubber pipe, a motor pump, and an air pump to build the system. We collect all parameters data for 45 days and continuously stored on fog layer. The project work was completed in vidarbh region of Maharashtra state where the temperature of summer exceeds 45^0C. Figure 1 show the hydroponics system for spinach plant

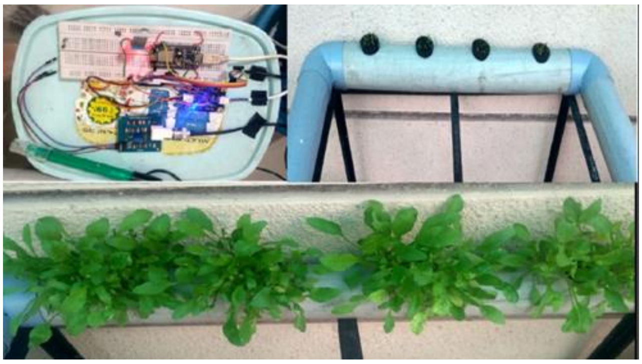

Fig 1. Hydroponics System with IoT

3.2. Dataset Description

A clever hydroponics system was created, and the leafy produce spinach was chosen for the case study. NFT (nutrient film techniques) is used to grow spinach in a hydroponic system, and reading parameters were recorded during the course of the following 45 days after the plant's germination. All-important characteristics are automatically tracked every day by various sensors after the germination process starts on day 4 and stored in the cloud. It was determined what the plants required to grow based on the data gathered by the sensors, therefore it was necessary to continuously check tds, Ph, temperature, EC, humidity, and water temperature. By turning on the motor, we can alter the nutrients in the tank and supply the hydroponics system if the cloud-stored figures change. If the water's pH deviates from or exceeds the advised range, we maintain the pH by adding the appropriate amount of Ph down or Ph up. Table 1 show standard parameter values required for the growth of spinach in hydroponics environment.

Table 1. Dataset Description

TDS in PPM	Days	Ph	Temperature	Water Temperature
Upto 150	1 to 4 days Normal Tap Water	6.0 to 7.0	23-30 c	21-27 c
150 to 300	5 to 12 days(1 week)	6.0 to 7.0	23-30 c	21-27 c
300 to 450	13 to 20 days(2 week)	6.0 to 7.0	23-30 c	21-27 c
450 to 600	21 to 27 days(3 week)	6.0 to 7.0	23-30 c	21-27 c
600 to 750	28 to 34 days(4 week)	6.0 to 7.0	23-30 c	21-27 c
750 to 900	35 to 40 days(5 week)	6.0 to 7.0	23-30 c	21-27 c
900 to 1200	Upto harvesting	6.0 to 7.0	23-30 c	21-27 c

3.3. Material Required

3.3.1. pH & EC or TDS Sensor

The pH sensor is one of the most important devices for measuring pH and is frequently employed in water quality monitoring. This kind of sensor can identify the alkalinity and acidity of liquids like water. Using an EC meter, you may rapidly and precisely determine the amount of nutrients in a solution.

Fig 2. pH and EC Sensor

3.3.2. DHT11 Sensor

The DHT11 sensor calibrates digital signals and detects temperature and humidity. It delivers a low-cost, high-quality device that is also accurate in calibration and quick to read.

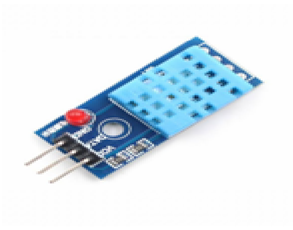

Fig 3. DHT11 Sensor

3.3.3. Water Temperature Sensor (DS18B20)

A temperature sensor is a tool used to track temperature changes in specific items by converting heat into electrical impulses. To understand or identify the symptoms of temperature fluctuations, the temperature sensor monitors the quantity of hot or cold energy produced by an object and provides analogue or digital outputs.

Fig 4. Water Temperature Sensor

3.3.4. NodeMCU(Microcontroller ESP32)

Node MCU is an freely available IoT platform with a minimum cost. It initially featured firmware that ran on Espressif Systems' ESP8266 Wi-Fi SoC. The Node MCU and ESP32 Wi-Fi Development kit is useful in creating Wi-Fi and bluetooth low energy (BLE) projects and applications.

Fig 5. ESP32 Microcontroller

3.4. Research Methodology

We developed intelligent hydroponics system for spinach plants figure 6 shows the architecture of our system. Data acquisition was done through various sensors such as EC sensor, DHT11 sensor, water sensor and pH sensor. These four sensors collect the seven parameters values continuously from the system through the IoT. All gathered data stored on fog layer daily and takes necessary action, after that these data are stored on cloud to find the accuracy of crop development. Before find accuracy through machine learning we apply preprocessing and feature extraction on dataset stored on cloud.

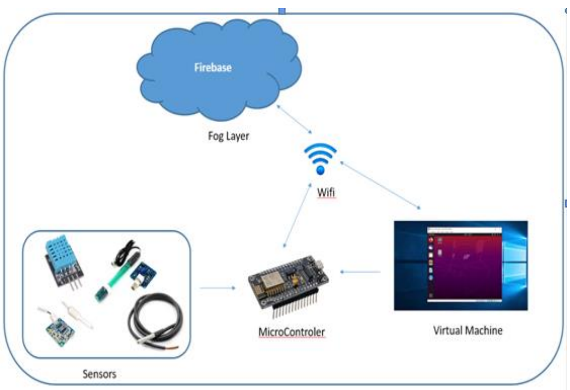

Fig 6. System architecture of IoT based hydroponics ESP32

3.5. Research Flow Diagram

Figure 7 shows how the data flow from system to cloud server. Depending on the dataset values, we performed necessary control action on our hydroponics system. Initially we fill the tank with external water and then add nutrients in the water by the nutrients tank. After filling the nutrients tank with water, this solution will transfer through the NFT channel in thin layer to the roots of plants. Plants will absorbed the necessary nutrients from the channel, different sensors collects the values from the tank and stored on fog through internet. From the values

Collected by sensors we had performed action to manage tds or pH. If tds is greater or less than prescribed range we performed action such as add water or add nutrients inside the tank and if the pH is greater than or less than required range we performed action to add pH down or pH up solution inside nutrients tank. These all action we done automatically and performed the action intelligently. After storing data on fog we had performed classification and regression machine learning algorithm on the dataset to predict the crop growth accuracy.

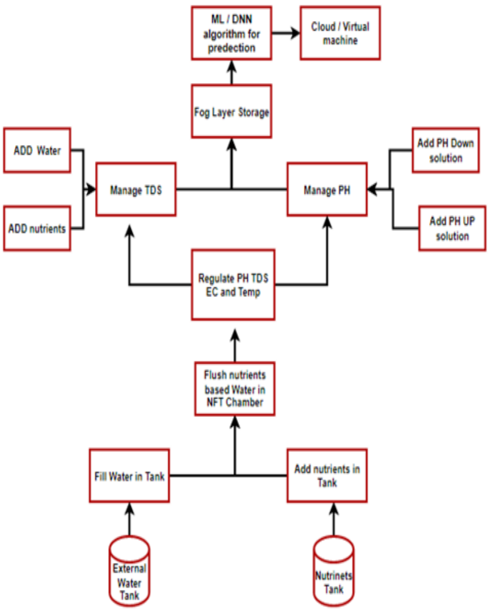

Fig 7. Data Flow Diagram

3.6. System Identification Model

3.6.1. Linear Regression

A straight forward machine learning approach used for predictive analysis is linear regression. Using this approach, the values are linearly correlated is Y target variable or the dependent variable and X is independent variable. A system with a single variable, such as x, is referred to as simple linear regression, whereas multiple linear regressions refer to a system with several input variables. In a linear regression, the relationship between the variables is shown as a straight line. The conventional slope-intercept form is used to calculate the best-fit line in linear regression.

$$y=mx+b \quad (1)$$

$$y=\text{p0} + \text{p1}x \quad (2)$$

Where, y= Target Variable (Dependant).

x= Independent Variable.

p0= intercept of the line.

p1 = Linear regression coefficient

3.6.2. Decision Tree

It is an algorithm for supervised machine learning. It is a graphic representation of every potential answer. A supervised learning-based data structure is the decision tree. Like a simple tree, the decision is based on specific conditions that pass from the root node through each of the nodes (children) with the input feature and divide to alternative solutions.

3.6.3. Least Absolute Shrinkage and Selection Operator (Lasso Regression)

The regression technique, also referred to as linear regression, presumes a linear relationship between the inputs and the target variable. An extension of linear regression is to penalize the loss function during training to promote simpler models with smaller coefficient values. These expansions are described by penalized linear regression and regularized linear regression [14]. Widely used Lasso Regression is a type of regularized linear regression with an L1 penalty. As a result, the coefficients for input variables that barely make a difference to the prediction task can decrease. This penalty allows for the automatic selection of features by deleting some coefficient values from the model by setting them to zero.

$$\sum_{i=1}^{n}(y_i - \sum_j x_{ij}\,\beta_j)^2 + \sum_{j=1}^{p}|\beta_j| \quad (3)$$

Amount of shrinkage is denoted by **λ** and **λ** is used to control the strength of L1 penalty. When **λ**=0 parameters are not deleted or eliminated, if **λ** increases bias increases and if **λ** decreases variance increases and.

3.6.4. Ridge Regression

The information is analyzed using ridge regression. This regression was crucial to bringing down the model's multi -collinearity and complexity. It also served to lower the coefficients. Ridge regression is an well known popular linear regression having L2 penalty. the cost function is determined by summing penalty similar to square of coefficients of magnitude. The relationship shown by the following equation

$$\sum_{i=1}^{M}(y_i - \hat{y}_i)^2 = \sum_{i=1}^{M}(y_i - \sum_{j=0}^{p} w_j \times x_{ij})^2 \lambda \sum_{j=0}^{p} w_j^2 \quad (4)$$

The coefficients of constraints denoted by (w) and the penalty term **λ** (lambda) regularize the coefficients if the coefficients take big values; It penalizes the optimization function.

3.6.5. Random Forest

Random forest (RF) and other supervised machine learning techniques are frequently used for classification and regression problems. It creates decision trees from a range of samples using the average for regression and the majority vote for categorization. Its capability to process data sets with continuous variables and categorical variables of regression in classification. For classification issues is one of Random Forest's key basic qualities, and it generates superior results.

In addition, as the trees grow, the random forest adds to the overall randomness of the model. Instead, than searching for the most fundamental attribute, nodes are separated by choosing the best trait out of a random assortment of qualities. As a result, there is a lot of variability, which frequently results in a better model [14]. The Random Forest (RF) algorithms employs Gini impurity by default but also provides Entropy as a substitute for classification. The following is the Gini Impurity mathematical function:

$$\sum_{i=1}^{C} fi(1 - fi) \quad (5)$$

Where C is the number of unique labels and fi is the frequency of label i at node.

3.6.6. Support Vector Machine

Support As a kernel-based machine learning model for classification and regression applications, One of the most popular supervised learning algorithms was proposed by Vapnik. The vector machine. The generalization and discriminative strength of SVM have recently drawn the interest of experts, practitioners, scholars, and academics. SVM has a strong theoretical foundation and generally provides excellent classification accuracy in practical applications. The SVM algorithm's objective is to find the most suitable decision line or boundary for organizing n-dimensional space so that more information can be put to the correct category quickly in the future. A hyperplane is the name given to this optimal decision boundary. The equation for hyperplane is

$$w.x + b = 0 \quad (6)$$

Where, w= A vector normal to hyperplane.

And b is an offset.

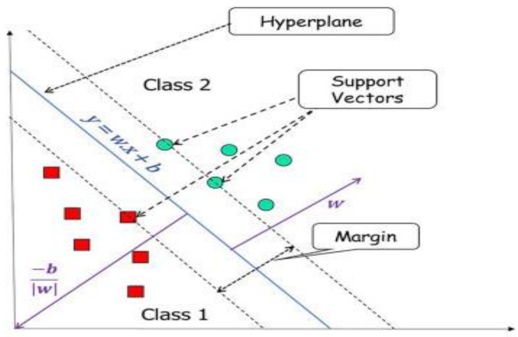

Fig 8. Support Vector Machine

3.7. Metrics Evaluation of ML Models

3.7.1. Mean Absolute Error (MAE)

The absolute difference between the dataset's actual and predicted values is added up to create the mean absolute error (MAE). It determines the dataset's mean residual value.

$$MAE = \frac{1}{N}\sum_{i=1}^{N}|yi - \hat{y}| \quad (7)$$

3.7.2. Mean Squared Error (MSE)

The total of the squared differences between a data collection's original and predicted values is known as the mean squared error (MSE). It establishes the remaining variance.

$$MAE = \frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y})^2 \quad (8)$$

3.7.3. Root Mean Square Error (RMSE)

Root Mean Squared Error (RMSE) is the square root of Mean Squared Error (MAE). It calculates the standard deviation of the residuals.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y})^2} \quad (9)$$

3.7.4. Coefficient of Determination (R^2)

The coefficient of determination (R^2) is the proportion of the variance of the dependent variable that can be predicted by the independent variables.

$$R^2 = 1 - \frac{\sum(y_i - \hat{y})^2}{\sum(y_i - \bar{y})^2} \quad (10)$$

4. Result Analysis and Discussion

4.1.1. Average values of all parameters captured by sensors

The average values of pH, TDS, and temperature are shown in Table 2. Values that are bolded indicate that they are outside of the acceptable range and must be controlled by taking the appropriate action. For instance, if pH is higher than 7, pH down must be used to maintain the water's pH. We automated the management of all parameter values in this way.

TABLE 02. Day wise Average values of pH, TDS and Temperature

Date	pH Range	Avg. pH	TDS Range	Avg. TDS	Temp. Range	Avg. Temp.
7/9/2022	6.0 to 7.0	6.83	150 t0 300	194.41	23 to 27 C	26.28
8/9/2022		6.83		194.41		26.28
9/9/2022		**7.1**		245.76		24.55
10/9/2022		6.85		260.62		24.31
11/9/2022		6.89		264.59		27.25
12/9/2022		6.9		280.91		26.93
13/09/2022	6.0 to 7.0	**7.08**	301 to 500	309.67	23 to 27 C	23.24
14/09/2022		6.96		440.62		23.91
15/09/2022		6.79		440.01		24.39
16/09/2022		**7.16**		430.73		26.66
17/09/2022		6.9		407.73		27.5
18/09/2022		6.8		477.15		24.68
19/09/2022	6.0 to 7.0	6.92	501 to 700	562.36	23 to 27 C	24.88
20/09/2022		6.72		530.17		25.73
21/09/2022		6.64		550.84		25.5
22/09/2022		6.76		585.81		27.8
23/09/2022		6.09		676.35		**29.9**
24/09/2022		6.2022		687.61		**30.11**
25/09/2022	6.0 to 7.0	6.2022	701 t0 900	**691.06**	23 to 27 C	**28.34**
26/09/2022		6.03		**691.31**		**30.01**
27/09/2022		6.41		704.56		24.39
28/09/2022		6.53		710.36		26.66
29/09/2022		6.54		800.3		27.5
30/09/2022		**5.83**		840.1		25.68

We collect data from hydroponics system for 45 days, after seedling of plants, the values collected from system are stored on fog layer daily. We used Amazon Web Services-Elastic compute cloud (AWS-EC2) is a Virtual Machine having Ubuntu as operating System to collect data from fog to run python script every day. On cloud we run python script which automatically finds the accuracy of crop growth daily, depending upon the values received from system we performed the respective action. Figure 9 shows the real time database stored on fog (firebase)

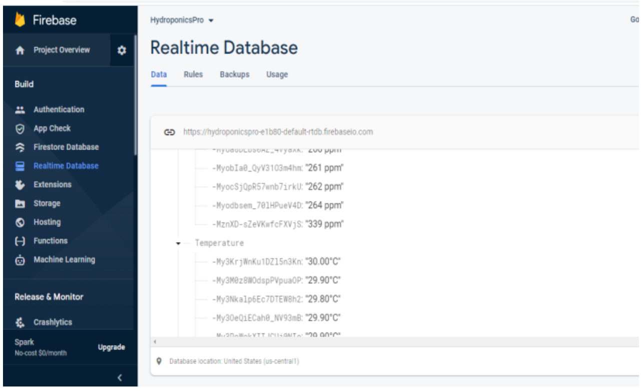

Fig 9. Real time data stored on firebase

Every night, all the parameter values were gathered and recorded in a csv file. The next day, the crop growth accuracy was determined using the supervised machine learning algorithm. The record of all the days accuracy was illustrated in figure 10

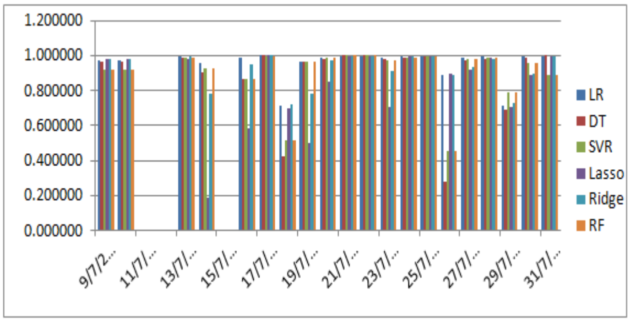

Fig 10. Day wise accuracy of Machine Learning Model

We checked our machine learning model with mean squared error (MSE), mean absolute error (MAE), root mean square error(RMSE) and coefficient of determination (R2). Table 3 gives the performance evaluation matrix of different machine learning (ML) models. Support Vector Regression (SVR) and Lasso has bets result performance on (R2=0.93), Support Vector Regression gave good result on (MAE=12.65 and RMSE= 21.31) and Lasso Regression having better performance on (MSE=4.51).

Table 03. Performance Matrix Evaluation of ML Models

Sr.No	Machine Learning Models	MAE	MSE	RMSE	R2
1	Linear Regression	12.74	4.64	21.55	0.9288
2	Decision Tree Regression	16.9	8.69	29.48	0.8668
3	Support Vector Regression	12.65	4.54	21.31	0.9304
4	Lasso Regression	14.38	4.51	21.23	0.9304
5	Ridge Regression	12.74	4.64	21.55	0.9288
6	Random Forest Regression	13.44	4.99	22.35	0.9234

We aggregate all the data at the time the plant is harvested to determine the accuracy of crop growth. Figure 11 displays the graph of machine learning model on each evaluation parameters.

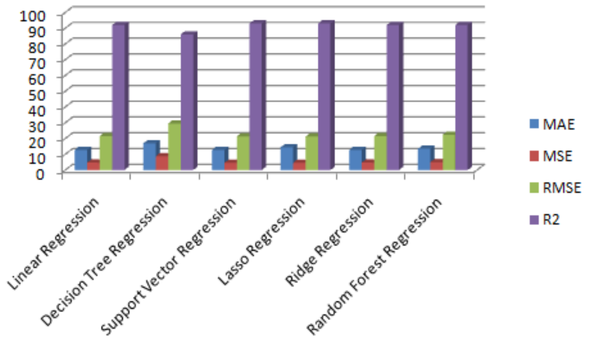

Fig 11. Evaluation metrics graph of ML model

5. Conclusion

Every developing nation, including India, is built on its agricultural sector. In order to meet the demand for food, hydroponics offers an alternative to conventional farming. In terms of precision, IoT and machine learning offer the better method to identify plant growth. By using the spinach plant as a case study, were able to construct a real-time hydroponics system. We apply machine learning (ML) algorithm to find the accuracy of crop growth on the real time database that had stored on the cloud. We found that Support Vector Regression and Lasso has best result on (Coefficient of Determination R2=0.93), Support Vector Regression (SVR) have good results on (Mean Absolute Error =12.65 and Root Mean Square Error = 21.31) and Lasso Regression (LR) have better result on (Mean Square Error=4.51).

Conflicts of interest

The authors declare no conflicts of interest.

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