Journal of Theoretical and Applied Information Technology
15th April 2024. Vol.102. No 7

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

SMART CROP PREDICTICTION USING STATISTICAL TECHNIQUES OF MACHINE LEARNING THROUGH IoT

PRABHAT KUMAR SAHU[1], SANGAM MALLA[1], MITRABINDA KHUNTIA[1], SMITA RATH[1], MANJUSHREE NAYAK [2]

[1]Department of Computer Science and Engineering, Siksha'O'Anusandhan Deemed to be University, Bhubaneswar, Odisha, India
[2] Department of Computer Science and Engineering, NIST , Berhampur, Odisha, India

E-mail: [1]prabhatsahu@soa.ac.in, [2]sangam.malla2015@gmail.com, [3]mitrabindakhuntia@soa.ac.in, [4]smitarath@soa.ac.in, [5]drmanjushreemishra@gmail.com

Abstract

The paper highlights the significance of agronomy in developing countries and the challenges faced in traditional farming methods, which rely heavily on human intervention. The solution proposed involves leveraging automation in agriculture, specifically using Internet of Things (IoT) sensors. By employing regular sensing and examination of crops through IoT sensors, combined with Machine Learning and statistical techniques, the system aims to predict the appropriate crop for an area that depends on factors like moisture in the soil, temperature, and humidity. The research emphasizes the need for such technology, particularly in countries like India, where agriculture is a predominant occupation. The system is designed to address issues such as repeated cultivation of the same crops and indiscriminate fertilizer use, which negatively impact crop yield and soil health. Ultimately, the proposed system intends to offer farmers insights into the best-suited crops for their land, along with information on required fertilizers and seeds, aiming to enhance profitability, encourage crop diversification, and mitigate soil pollution.

Keywords:- *Smart Agronomy, Soil Fertility, Machine Learning, Statistical Techniques, Smart Crop Prediction.*

1. INTRODUCTION

Agriculture is a very important occupation for a large part of the Indian population and it also provides a blockish contribution to the Indian economy. Keeping in view the facts of the past years, it has been seen that the quantity of grain yield in Agriculture in India has been reduced and the consequence is that the price level of the crop is simultaneously increased [1,2].

If seen, there are many different regions due to which the production of corn has decreased such as climate change, disease, fertilizer abuse, low soil fertility, water wastage, etc. Keeping this growing concern in mind, we should make changes in agriculture, and the ultimate solution of this problem is to combine those wireless sensors to IoT [3,4]. Internet of Things is among the one that keeps everything connected on the internet. Its main purpose is that it provides the right fact to the right person at the right time [5, 30]. Water for irrigation is a key factor in agriculture, file timing and magnitude of season-wise rain cannot be predicted in advance [6, 31].

Need of Prediction and automatic irrigation:

- In automatic irrigation, farmers will have the knowledge as well as the provision to supply required amount of water in required time [7].
- This method saves more amount of energy and resources.
- It is easy to predict the type of crop suitable for that region.
- This method automatically controls soil moisture level thus decreasing the errors conducted by the humans [10, 23].
- In greenhouse, we can easily predict the type of vegetable that can be yielded using moisture, temperature and soil fertility checking sensors.
- The motors are used in agriculture automatically by using controls and no need for labor to turn the motor on or off manually [11].
- It also reduces runoff from over watering and over fertilizing saturated soils which will improve crop productivity [12,22].
- It also informs the exact amount of pesticide required for a particular type of crop.

This mission makes use of IoT generation in agriculture; amazing vegetation increases environmental parameters in a set location to assist

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

farmers to find the problem in time [13, 14, 21]. Agriculture professionals deliver pointers with statistics to upswing the farmers' earnings and assist them with the precaution and management of the harvest disease and pests [15, 16, 25]. With the developments of different apps, different merchandise advertises agricultural generation along with valuable FAQ in online mode from the professionals [24, 26]. We can bring machine improvements by imposing improvements in Server, Android, Pc's and its extensibility.

2. LITERATURE SURVEY

The information is collected and analyzed by the specialists who bring a comparison between the traditional work productivity and atmospheric impact. They are targeting crop observation; data of temperatures and the precipitation that will be collected and analyzed for initiating different methods to scale the failures of crops and to improve the plant production [17, 27]. The basic surveillance on the automated irrigation system helps to watch the crop fields and send appropriate data to the control system [18, 29].The data received or being collected from the wireless sensors are then forwarded to the server database by wireless transmission network[19,20]. During the process of automatic irrigation, if the temperature falls or any circumstances will arise which will break the barrier of the potential range specified by the user, then it will monitor it, inform the user about it and it will provide an interface for the user in order to take necessary steps in order to protect the crops or to give proper nutrition for the proper growth of the crops [30].

- Prof. K.A.Patil and Prof.N.R.Kalehad already initiated a new model of irrigation by smarter way through ICT. The entire period and the historical atmosphere are anticipated to assist to attain economical management and exploitation of recourses [1].
- Mahammad ShareefMekala, Dr.P.Viswanathandetermined some typical use of Agriculture IoT detector to Monitor Network Technologies applying cloud computing as a backbone [8, 32, 33].
- Prathibha S.R, AnupamaHongal,Jyothi M.P.had created temperature recording sensors which will record the agricultural field temperature, capture the situation through a camera and send it to the user for necessary action [3, 34, 35].
- International Journal of Engineering Science Research Technology implements some Machine Learning Techniques which predicts the type of crop productivity in Tamil Nadu. By using Random Forest algorithm, this paper focuses on the existing data of predicting the yield of the crop. The samples along with the models were tested by collecting appropriate data from Tamil Nadu Data centers. The accurate crop yield prediction could be used for Random Forest Algorithm [9].

3. PROBLEM STATEMENT

Modern agriculture faces numerous challenges such as inefficient resource utilization, unpredictable weather patterns, and the need for increased productivity to meet the growing global demand for food. In addressing these challenges, the integration of Internet of Things (IoT) technologies into agricultural practices, commonly known as Smart Agriculture, has emerged as a promising solution. However, several critical issues need to be addressed to ensure the successful implementation and widespread adoption of Smart Agriculture.
The initial investment required to deploy IoT infrastructure in agriculture, including sensors, actuators, and communication networks, can be prohibitive for small and medium-sized farmers. Cost-effective solutions are needed to make Smart Agriculture accessible to a broader range of agricultural practitioners.
Many farmers may not have the necessary technical skills to effectively operate and maintain IoT devices. Training programs and user-friendly interfaces are needed to empower farmers with the knowledge and skills required to leverage Smart Agriculture technologies.
Different crops, climates, and farming practices require tailored solutions. Creating a flexible framework that allows customization to suit the unique needs of diverse agricultural settings is essential for the widespread adoption and success of Smart Agriculture.
Machine learning (ML) models have demonstrated remarkable success in various domains, ranging from healthcare to finance, yet the deployment and optimization of these models present a set of challenges that need to be addressed for widespread and effective utilization. Machine learning models heavily rely on data quality, and biases present in training data can lead to biased predictions. Ensuring data quality,

addressing bias, and promoting fairness in models are critical concerns, especially in applications that impact individuals or societal groups.

As machine learning models become more complex, deploying them at scale presents challenges related to computational resources, memory requirements, and real-time processing. Optimizing models for efficiency while maintaining high accuracy is a delicate balance, particularly in resource-constrained environments. Addressing these challenges is essential for realizing the full potential of machine learning models across diverse applications. Overcoming these obstacles will contribute to the development of more transparent, reliable, and ethical machine learning solutions that can be effectively integrated into real-world scenarios.

3. PROPOSED WORK

The proposed system aims to predict the optimal crop for a specific piece of land by considering key factors like contents present in the soil and parameters affecting the weather. The block diagram is reflected in Figure 1 and data flow diagram is reflected in Figure 05.

A. **Sensor Data Collection: -** Rainfall detection sensor will record the temperature, dampness and the humidity of the agricultural field and send the data to the Arduino Uno Control system for further action.
B. **Wireless data transfer: -**Wi-Fi model is used to send the recorded data to the web server using any wireless networks.
C. **Data handling and Decision-making: -** The whole system is dependent on what data is to be recorded by the sensor. After getting appropriate data from the sensors, the values will be checked in the program coding and if any abnormality is found then the control system instructs to either switch ON or switch OFF the motor accordingly.
D. **Automation and Irrigation system: -** In order to implement the automated irrigation system, different methods are adapted by the system. It includes a number of relays, control system, web servers which work together to take necessary steps depending on sensor's data.
E. **Web Application: -** The provision of designing a web application is necessary as it will help the users to retrieve the data recorded by the sensors and allow the user to take vital steps if necessary through the user-friendly application.
F. **Mobile Application: -** As this is the era of smart phone users, so mobile application benefited with web server accessibility through any wireless communication will definitely help the user to take vital steps at any time irrespective of any place.
G. **Machine Learning Algorithm:-** The utilization of machine learning algorithms are based upon prediction, emphasizing the optimized estimation of likely outcomes based on trained data. Predictive analytics, incorporating data, statistical algorithms, and machine learning, is described as a means to identify the likelihood of future outcomes by analyzing historical data. The system in question employs supervised machine learning algorithms, specifically focusing on subcategories like classification and regression. In this context, the classification algorithm, particularly the Decision Tree algorithm, is deemed most suitable for predicting crops, while the Support Vector Machine (SVM) algorithm is specified for rainfall prediction within the system.
H. **Prediction of Rainfall:-** The process begins with loading an external dataset containing previous year rainfall data. Subsequently, the dataset undergoes pre-processing, as outlined in the Data Pre-processing section. Following this pre-processing step, the model is trained using an SVM classifier with a Radial Basis Function (RBF) kernel. The classifier is then fitted to the training set, and the Radial Basis Function is expressed mathematically, as indicated by equation (1).

$$V(P1,P2)= \text{Exponent}\ (-\gamma \|p1-p2\|^2) \quad \ldots\ldots(1)$$

Where,

|p1-p2| are defined as the distance described by Eucliden between P1 and P2.

γ- is termed as Gamma

After fitting and testing the model, it is used to predict the annual rainfall. The predicted rainfall serves as one of the input parameters for the crop prediction system.
I. **Crop Prediction**:- The crop prediction process begins by loading external crop datasets, followed by various stages of pre-processing detailed in the Data Pre-processing section. After completing data pre-processing, the models are trained using a Decision Tree classifier on the training set. To predict the crop, factors like temperature, humidity, soil pH, and predicted rainfall are considered as input parameters for the system. These parameters can be manually

entered or obtained from sensors. The input values, including predicted rainfall, are then appended to a list. The Decision Tree algorithm utilizes this list data to predict the crop.

J. **Crop Recommendation:-** The system recommends the most suitable crop for cultivation based on predicted rainfall, soil contents, and weather parameters. Additionally, it provides information on required fertilizers such as Nitrogen (N), Phosphorus (P), and Potassium (K) in kilograms per hectare, along with the necessary seed quantity in kilograms per acre for the recommended crop. Furthermore, the system includes features like displaying current market prices and approximated yield in quintals per acre for the recommended crop. These details aim to assist farmers in selecting the most profitable crop

K.

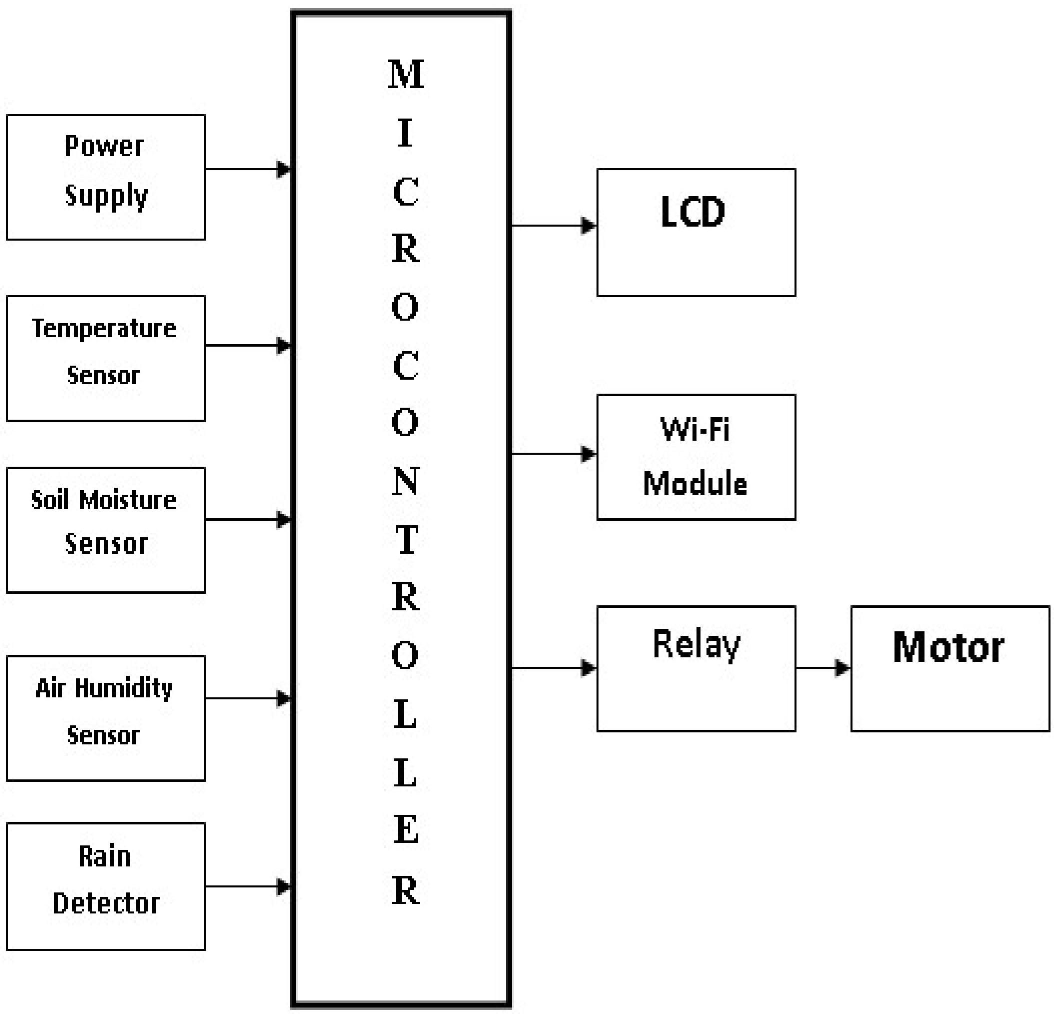

Figure 1: Block Diagram Of The Proposed Work

3.1 Hardware Used

- **Soil Humidity Sensor: -** The sensors that are used to check the humidity of the soil of agricultural field are termed as Soil Humidity sensor as shown in Figure 2. The sensors that will be used can be either analog or Digital. We use digital sensor in order to receive static output and analog sensors to receive threshold output.

Figure 2:Soil Humidity Sensor

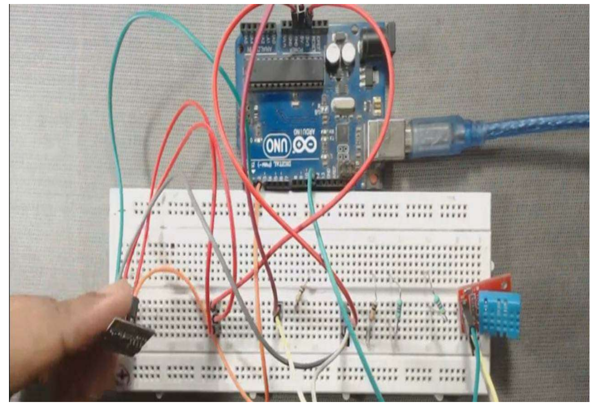

Figure 3: Temperature Sensor

● **Temperature Sensor:** We have used LM35 sensor as shown in Figure 3 whose output voltage is 5V and has a large operational range. Its rise in temperature is directly proportional to output voltage in mV. The reading capability of the sensor ranges from -55 degrees to 150 degrees consuming minimum electricity.

● **Humidity Sensor:** As because of its micro size with power consumption considerably low and signal throughput of about 20 meters, this DHT11 humidity sensor is the best choice for various applications. It has a complex of humidity sensors with a digitally calibrated signal output to ensure versatility and stability.

● **Rain Detection Sensor:** This sensor contains a resistance-type moisture measurement component that falls through the raining board and also to measure the rain intensity and connected to a power supply which may be of 5V, the LED glows when the induction board has no raindrops and the D_0 output is high. When a small amount of water drips, the D_0 output is low, the switch indicates lights up, brushes off the water droplets, and generates a high level when it is reset to the initial state. Wi-Fi module facilitated for appending Wi-Fi functionality through serial UART communication, features include 802.11 protocol

Figure 4:Rain Detection Sensor

Journal of Theoretical and Applied Information Technology
15th April 2024. Vol.102. No 7

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

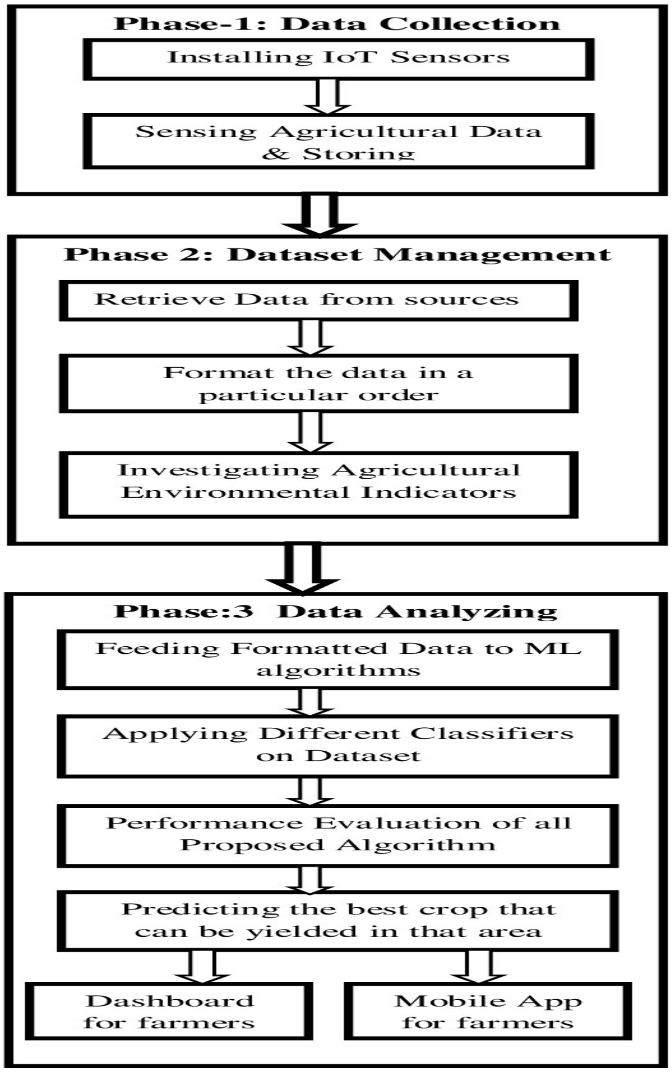

Figure 5: Data Flow Diagram

4. METHODOLOGY

According to our research study, we use the different sensors associated with IoT along with the approaches like machine learning to predict the yielding of crops in different regions. We have used the data collected from our different IoT sensors in our research work. SVM algorithms based on machine learning have been used in our research work. The accurate predictions of crop yielding have been successfully achieved through the comparison of these algorithms.

4.1 Dataset

The dataset is completely based on the records collected from different sensors of IoT. These datasets are then fed to different ML algorithms. The ML algorithm will evaluate the records or the dataset and predict the most appropriate crop that can be yield at that particular area. Generally, the amount of rainfall and temperature affects the climate which in turn also affects the productions of crops in a particular region. The different type of pesticides and the quality of soil also affects the environmental factors for the growth of the crop in that region. Similarly, our research will give a proper report about the type of crop in that particular area in India every year. The dataset is reflected in Table 1.

4.2 Preprocessing

Data cleaning is the first task of the researcher after gathering all the related data which we have collected from our sensors. After completing the data cleaning process, the researcher finds out all the common columns from the data and then

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

merges it into related data frames. Therefore, in order to maintain a general standard for every attributes the researcher takes the help of normalization process. Thus the final data frame includes all the feature like type of crop, origin country, year of cultivation, yielding value, average rainfall in mm, pesticides used and temperature recorded. Different algorithms that rely upon machine learning predict the cultivation of crops and for practicing the best results a brief comparison on algorithms have been done. For predicting the best crop yielding we have used as well as compared the following models based on machine learning. The final dataset used is shown in fig.01 and the co-relation matrix is shown in fig.06.

Table 1: Sample Of Final Dataset

Sl. No.	Temperature	Humidity	ph	Rainfall	Label
1	21.879346	83.002745	6.402487	203.935257	rice
2	22.770441	81.319684	7.138145	227.655555	rice
3	22.004159	81.319258	7.940157	264.964847	rice
4	27.491248	81.158489	6.880198	243.864987	rice
5	21.130157	82.606543	7.728657	2624712454	rice

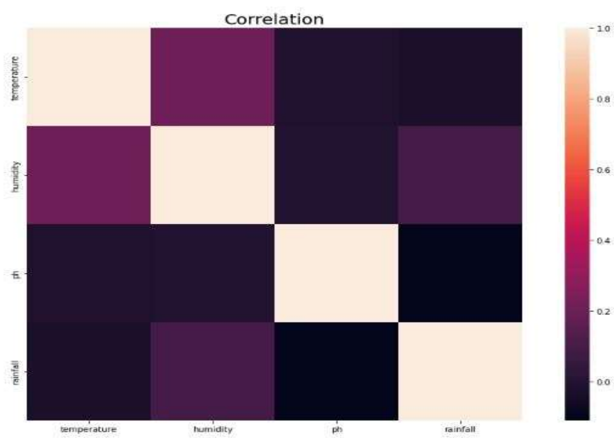

Figure 6: Co-Relation Matrix After One Hot Encoding

- **SVC:**
  The machine learning classification problems are minimized by SVM's. The model that is used to implement SVM's is called as Support Vector Classifier (SVC). It finds outs the amount of error that can be accepted in our model and deliver a hyper plane to fit the data. In our research SVC proves best to calculate and implement SVM.

By combining all the four different data sets collected from different sensors, the final data frame with all required features is obtained. In order to reveal the relationship among different features, a correlation matrix is developed. This co relation matrix is considered as heat map from the above correlation as shown in fig-06.

Thus the fig.02 clearly shows that the variables have neither relationship nor correlation among themselves. Therefore, each and every feature is independent. Considering our data frame, the two columns, product and origin countries contain the categorical data values that have label value instead of numeric value. There are many algorithms based on machine learning which cannot work on the models that are directly dependent on labeled data, rather they use variables in both input and output stream which can work on numeric values. Therefore, the categorical data needs to be converted to numeric values in order to convert them we need a definite encoding process. Using this encoding process a dedicated form is obtained from categorical data and feed to different algorithms following machine learning for obtaining better predictions. Our data frames that contained products and origin country columns having categorical data converted to numeric array through definite encoding process. Execution of this encoding process returns a

matrix by creating a binary column under every category.
After successful execution of data, the processed data is categorized into training and testing carrying split factor of 0.7. This in term means that we will use 70% of data from the dataset for training purpose and 30% from the same remaining dataset for testing purpose. The 70% training data set is considered as the primary data set which will be used as input to machine learning algorithms for predicting the exact production value. On the other hand, the 30% test data will be used to examine the accuracy level when the training data is given as input to machine algorithms.

5. EXPERIMENT AND RESULTS

The suggested system advises on the most fitting crop for a specific piece of land, taking into account factors such as annual rainfall, temperature, humidity, and soil pH. The system autonomously predicts annual rainfall using the SVM and RFC algorithm based on past year data, while the user needs to input other parameters. In the results section, the system presents information on the recommended crop, necessary seeds per acre, market price, and an estimated yield for the suggested crop. Furthermore, the system considers NPK values in the input section to provide details on the required Nitrogen, Phosphorus, and Potassium for the recommended crop. The Confusion Matrix generated from SVM is shown in fig. 07. The ROC Curve produced through SVM is shown in fig.08 and the class prediction error is found in fig 09.
The comparison of classification report of SVM is shown in the following Table 2 :

Table 2: Classification Report Of SVM Classifier

Samples	Precision	Recall	F1-score	Support
apple	0.71	0.96	0.81	23
banana	0.87	0.95	0.91	21
blackgram	0.91	1	0.95	20
chickpea	1	0.96	0.98	26
coconut	0.96	1	0.98	27
coffee	0.75	0.88	0.81	17
cotton	0.8	0.94	0.86	17
grapes	0.93	0.93	0.93	14
jute	0.77	1	0.87	23
kidneybeans	0.91	1	0.95	20
lentil	0.65	1	0.79	11
maize	0.84	0.76	0.8	21
mango	0.83	1	0.9	19
mothbeans	1	0.67	0.8	24
mungbean	0.95	0.95	0.95	19
muskmelon	0.94	1	0.97	17
orange	0.8	0.57	0.67	14
papaya	1	0.83	0.9	23
pigeonpeas	1	0.48	0.65	23
pomegranate	0.74	0.61	0.67	23
rice	1	0.74	0.85	19
watermelon	0.95	1	0.97	19
accuracy			0.87	440
macro avg	0.88	0.87	0.86	440
weighted avg	0.89	0.87	0.87	440

Journal of Theoretical and Applied Information Technology
15th April 2024. Vol.102. No 7

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

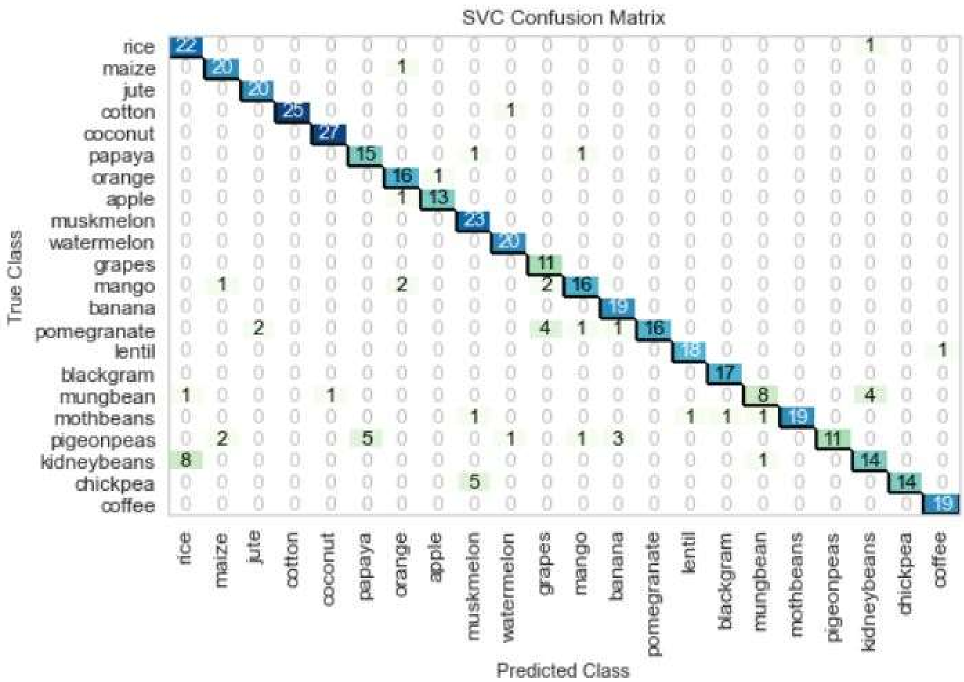

Fig. 07 Svm Confusing Matrix

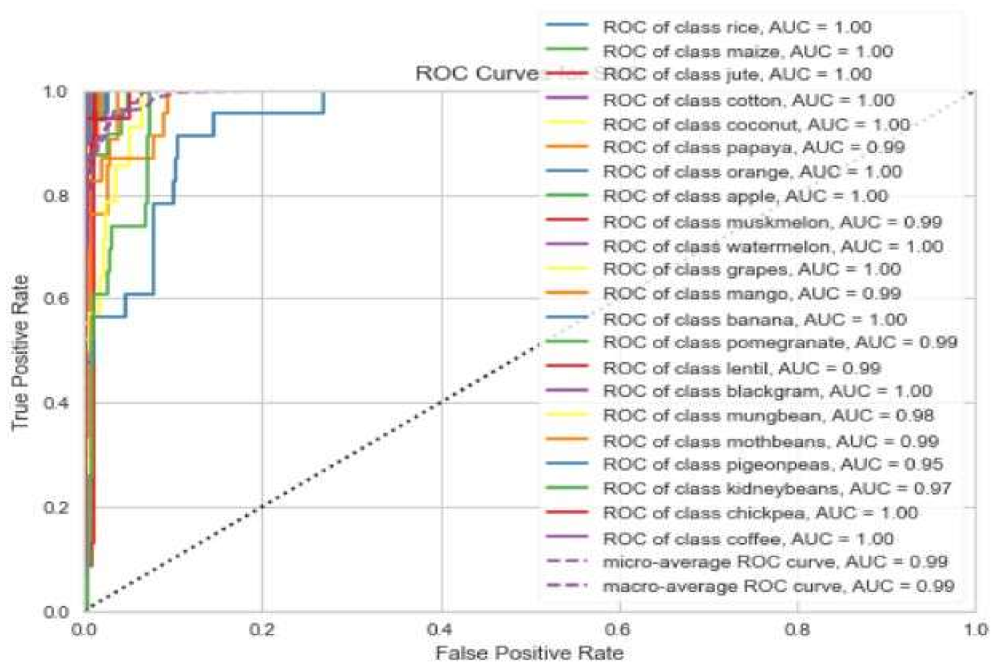

Fig.08:- ROC Curve Of SVM

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

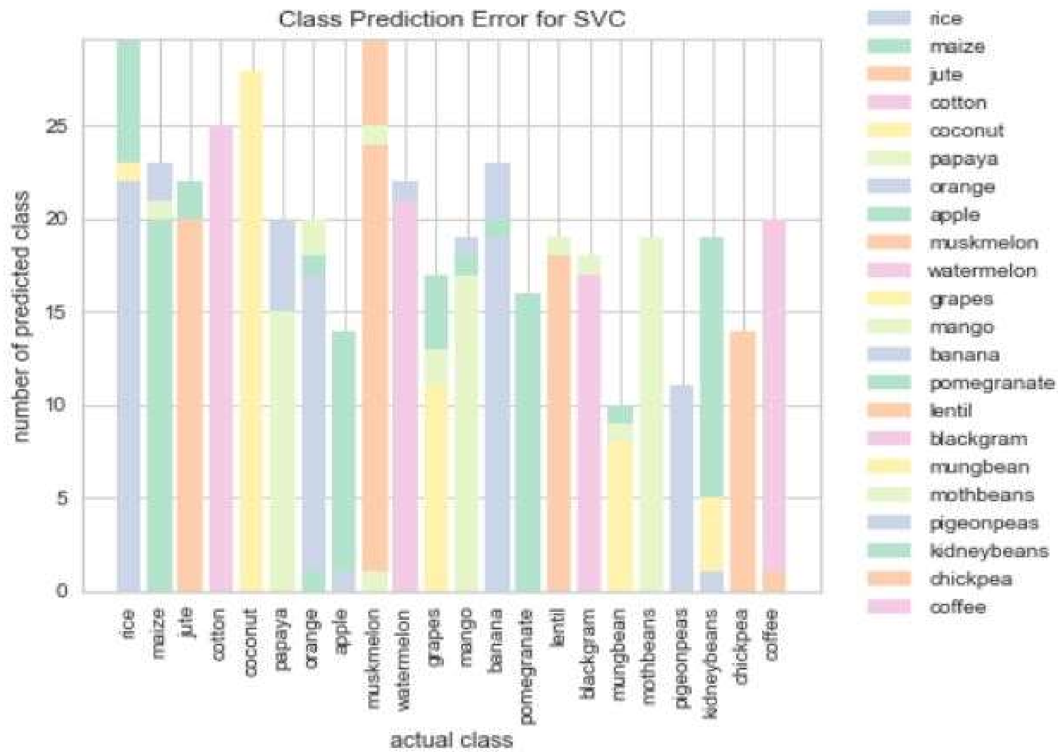

Fig.09:- Class Prediction Error For SVM

We took the help of Rooted Square value in order to compare the above mentioned models. The coefficient of determination i.e. R^2 which can also be referred as Regression Score function is taken as input in order to calculate the evolution matrix of all the models mentioned above in our research work. The coefficient can be used to find out the variance proportion for product column. The positioning of data points either in curve or in line is decided by R^2 score. After comparing all the values and getting the result as shown in fig.10, we conclude that the highest R^2 score is 94% from SVM technique.

Fig.10- Result Shown In LED Screen After Sensor Detection

MODEL RESULTS AND CONCLUSION

Generally, which data model fits perfectly the observed data set is decided by the R- Square interpretation. Considering an example, we can conclude that 94% of the data gets fitted perfectly well by Regression model if the value of R-Square interpretation is 94%. The model results are displayed in fig.10.

The R squared value is directly proportional to the data set fitting which means the greater the value of R-Square model, the best is the fitting of the data set values. Thus considering the above criteria, it can be definitely said that in our research work, SVM perfectly fits the data set values as it returns a highest value of 94%.

In this case we can try for the node probability which can be calculates as the total number of products that reaches the node by the cardinality of the product samples. Thus the feature importance rises with the rise in value of the node probability. The node feature value [19, 20] is considered as the best value recorded and the value recorded in our research work is [15, 17, 18] through SVM.

6. CONCLUSION:

Automated Irrigation system under IoT is described in this article. The smart irrigation system comprises of different IoT hardware, along with some control systems, web servers, and cloud communications. This system will automatically record all the environmental parameters and send them to store in cloud storage using wireless communications. The user will take control of the actions depending on whether it is done using the actuator. This advantage allows the farmer to improve the crop as well as predict the type of crop suitable for that particular region. The aim is to empower farmers to make informed decisions, fostering agricultural development through innovative ideas. The aim is to empower farmers to make informed decisions, fostering agricultural development through innovative ideas.

REFERENCES:-

[1] Patil, K. A., & Kale, N. R. (2016, December). A model for smart agriculture using IoT. In *2016 international conference on global trends in signal processing, information computing and communication (ICGTSPICC)* (pp. 543-545). IEEE.

[2] Ratnaparkhi, S., Khan, S., Arya, C., Khapre, S., Singh, P., Diwakar, M., & Shankar, A. (2020). Smart agriculture sensors in IOT: A review. *Materials Today: Proceedings*.

[3] Prathibha, S. R., Hongal, A., &Jyothi, M. P. (2017, March). IoT based monitoring system in smart agriculture. In *2017 international conference on recent advances in electronics and communication technology (ICRAECT)* (pp. 81-84). IEEE.

[4] Mat, I., Kassim, M. R. M., Harun, A. N., &Yusoff, I. M. (2018, November). Smart agriculture using internet of things. In *2018 IEEE conference on open systems (ICOS)* (pp. 54-59). IEEE.

[5] Khoa, T. A., Man, M. M., Nguyen, T. Y., Nguyen, V., & Nam, N. H. (2019). Smart agriculture using IoT multi-sensors: a novel watering management system. *Journal of Sensor and Actuator Networks*, *8*(3), 45.

[6] Lakhwani, K., Gianey, H., Agarwal, N., & Gupta, S. (2019). Development of IoT for smart agriculture a review. In *Emerging trends in expert applications and security* (pp. 425-432). Springer, Singapore.

[7] Jain, A. A., & Kumar, A. (2020). Smart agriculture monitoring system using IOT. *International Journal for Research in Applied Science & Engineering Technology*.

[8] Mekala, M. S., & Viswanathan, P. (2017, August). A Survey: Smart agriculture IoT with cloud computing. In *2017 international conference on microelectronic devices, circuits and systems (ICMDCS)* (pp. 1-7). IEEE.

[9] Sen, S., &Madhu, B. (2017). International journal of engineering sciences & research technology smart agriculture: a bliss to farmers. *Int. J. Eng. Sci. Res. Technol.*, *6*(4), 197-202.

[10] Channe, H., Kothari, S., & Kadam, D. (2015). Multidisciplinary model for smart agriculture using internet-of-things (IoT), sensors, cloud-computing, mobile-computing & big-data analysis. *Int. J. Computer Technology & Applications*, *6*(3), 374-382.

[11] Reddy, K. S. P., Roopa, Y. M., LN, K. R., &Nandan, N. S. (2020, July). IoT based smart agriculture using machine learning. In *2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA)* (pp. 130-134). IEEE.

[12] Yahata, S., Onishi, T., Yamaguchi, K., Ozawa, S., Kitazono, J., Ohkawa, T., ...& Tsuji, H. (2017, May). A hybrid machine learning approach to automatic plant phenotyping for smart agriculture. In *2017 International Joint Conference on Neural Networks (IJCNN)* (pp. 1787-1793). IEEE.

[13] Pathan, M., Patel, N., Yagnik, H., & Shah, M. (2020). Artificial cognition for applications in smart agriculture: A comprehensive review. *Artificial Intelligence in Agriculture*, *4*, 81-95.

[14] Abraham, G., Raksha, R., &Nithya, M. (2021, April). Smart Agriculture Based on IoT and Machine Learning. In *2021 5th International Conference on Computing Methodologies and Communication (ICCMC)* (pp. 414-419). IEEE.

[15] Bu, F., & Wang, X. (2019). A smart agriculture IoT system based on deep reinforcement learning. *Future Generation Computer Systems*, *99*, 500-507.

[16] Yin, L., & Zhang, Y. (2020). Village precision poverty alleviation and smart agriculture based on FPGA and machine learning. *Microprocessors and Microsystems*, 103469.

[17] Hassan, S. I., Alam, M. M., Illahi, U., Al Ghamdi, M. A., Almotiri, S. H., &Su'ud, M. M. (2021). A systematic review on monitoring and advanced control strategies in smart agriculture. *IEEE Access*, *9*, 32517-32548.

[18] Escamilla-García, A., Soto-Zarazúa, G. M., Toledano-Ayala, M., Rivas-Araiza, E., &Gastélum-Barrios, A. (2020). Applications of artificial neural networks in greenhouse technology and overview for smart agriculture development. *Applied Sciences*, *10*(11), 3835.

[19] Junior, F. M. R., Bianchi, R. A., Prati, R. C., Kolehmainen, K., Soininen, J. P., &Kamienski, C. A. (2022). Data reduction based on machine learning algorithms for fog computing in IoT smart agriculture. *Biosystems Engineering*.

[20] Varman, S. A. M., Baskaran, A. R., Aravindh, S., &Prabhu, E. (2017, December). Deep learning and IoT for smart agriculture using WSN. In *2017 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)* (pp. 1-6). IEEE.

[21] Kumar, S., Chowdhary, G., Udutalapally, V., Das, D., &Mohanty, S. P. (2019, December). GCrop: Internet-of-Leaf-Things (IoLT) for monitoring of the growth of crops in smart agriculture. In *2019 IEEE International Symposium on Smart Electronic Systems (iSES)(Formerly iNiS)* (pp. 53-56). IEEE.

[22] Shaikh, F. K., Memon, M., Mahoto, N. A., Zeadally, S., &Nebhen, J. (2021). Artificial intelligence best practices in smart agriculture. *IEEE Micro*.

[23] Rosenstock, T. S., Lamanna, C., Chesterman, S., Bell, P., Arslan, A., Richards, M. B., ...& Zhou, W. (2016). The scientific basis of climate-smart agriculture: A systematic review protocol. *CCAFS Working Paper*.

[24] Issad, H. A., Aoudjit, R., & Rodrigues, J. J. (2019). A comprehensive review of Data Mining techniques in smart agriculture. *Engineering in Agriculture, Environment and Food*, *12*(4), 511-525.

[25] Tsige, M., Synnevåg, G., &Aune, J. B. (2020). Gendered constraints for adopting climate-smart agriculture amongst smallholder Ethiopian women farmers. *Scientific African*, *7*, e00250.

[26] Janc, K., Czapiewski, K., &Wójcik, M. (2019). In the starting blocks for smart agriculture: The internet as a source of knowledge in transitional agriculture. *NJAS-Wageningen Journal of Life Sciences*, *90*, 100309.

[27] Chuang, J. H., Wang, J. H., &Liou, Y. C. (2020). Farmers' knowledge, attitude, and adoption of smart agriculture technology in Taiwan. *International Journal of Environmental Research and Public Health*, *17*(19), 7236.

[28] Abdel-Basset, M., Shawky, L. A., &Eldrandaly, K. (2020). Grid quorum-based spatial coverage for IoT smart agriculture monitoring using enhanced multi-verse optimizer. *Neural Computing and Applications*, *32*(3), 607-624.

[29] Totin, E., Segnon, A. C., Schut, M., Affognon, H., Zougmoré, R. B., Rosenstock, T., & Thornton, P. K. (2018). Institutional perspectives of climate-smart agriculture: A systematic literature review. *Sustainability*, *10*(6), 1990.

[30] Mukherji, S. V., Sinha, R., Basak, S., &Kar, S. P. (2019, February). Smart agriculture using internet of things and mqtt protocol. In *2019 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon)* (pp. 14-16). IEEE.

[31] Malla, S., Sahu, P. K., Patnaik, S., & Biswal, A. K. (2023). Obstacle Detection and Assistance for Visually Impaired Individuals Using an IoT-Enabled Smart Blind Stick. *Revue d'Intelligence Artificielle*, *37*(3).

[32] MALLA, S., SAHU, P. K., PATNAIK, S., & NAYAK, M. (2023). Smart energy efficient techniques for IOT enabled wireless node. *Journal of Theoretical and Applied Information Technology*, *101*(18), 7331-7346.

[33] Malla, S., Sahu, P. K., Sarangi, D., & Patnaik, S. (2022). Role of Smart Dustbin in Creating a Smart Environment. In *Smart Cities and Smart Communities: Empowering Citizens through Intelligent Technologies* (pp. 113-129). Singapore: Springer Nature Singapore.

[34] Malla, S., Sahu, P. K., Patnaik, S., Biswal, A. K., & Nayak, M. (2023). IoT-Enabled Smart Anti-Smog Towers: A Novel Approach to Urban Air Pollution Control. *Ingénierie des Systèmes d'Information*, *28*(6).

[35] Routray, P. K., Pattanayak, B. K., & Mohanty, M. N. (2022). An IoT Application Framework Using Deep Learning for Face Mask Detection. *Specialusis Ugdymas*, *1*(43), 5450-5464.