Crop Yield Prediction using Granular SVM

G. Sudha Sadasivam

Abstract: Agriculture is the backbone of the Indian economy. Farming is a major source of income for many people in developing countries. Prediction of yield of crops is desirable as it can predict the income and minimize losses for the farmers under unfavorable conditions. But predicting crop yield is a challenging task in developing countries like India. Conventionally, crop yield prediction is done using farmer’s expertise. The sustainability and productivity of a crop growing area are dependent on suitable climatic, soil, and biological conditions. So, data mining techniques based on neural networks, Neuro-Fuzzy Inference Systems, Fuzzy Logic, SMO, and Multi Linear Regression can be used for prediction. Previous work has performed yield prediction based on crop models considering only some of the environmental factors. This work uses a Support Vector Machine (SVM) to predict the crop yield under different environmental conditions that include soil, climate, and biological factors. Applying granular computing enables dividing the problem space into a sequence of subtasks. So, the hyperplane construction of SVM can be parallelized by splitting the problem space. Testing can also be parallelized. The main advantage is that linear SVM can be used to handle higher dimension space. Time complexity is reduced. Prediction using granular SVM can be parallelized using appropriate techniques like MapReduce/GPGPU. IoT-based agriculture increases crop yield by accurate prediction, automation, remote monitoring, and reducing wastage of resources. IoT-based monitoring systems can be used by farmers, researchers, and government officials to analyze crop environments and statistical information to predict crop yield. This paper proposes an IoT-based system to predict crop yield based on climatic, soil, and biological factors using parallelized granular support vector machines.

Keywords: Yield Prediction, SMO, Granular Support Vector Machines, MapReduce, GPGPU, IoT, Automation, Remote monitoring.

I. INTRODUCTION

Agriculture is the spine of the Indian economy. 69% of the Indian population has agriculture as their main occupation or side business. Predicting crop yield is a challenging and desirable task for decision-makers in developing countries like India. Such predictions can minimize losses under unfavorable conditions and maximize gain under favorable conditions. Farmer’s expertise plays a major role in predicting crop yield. The Internet of things (IoT) enables users to organize, obtain and consume information by connecting real-world objects. IoT enables various applications in the digital agriculture domain. IoT-based agriculture can predict crop yield. With the advent of IoT, wireless sensor networks and the web play an important role in the digital agriculture domain. A wireless sensor network is a network composed of a set of nodes integrating the functions of acquiring, processing, communicating. Once deployed, the nodes cooperate autonomously to collect and transmit data to a base station for monitoring and controlling a device. Precision agriculture can be defined as the art and science of using technology to improve crop production. This paper uses a basic IoT system to sense soil parameters, humidity, temperature, and sunshine. The sensed information is used as test data for prediction in granular SVM (GSVM) to predict crop yield. A lot of research has been carried out in applying data mining techniques for crop yield prediction.

II. LITERATURE SURVEY

IoT frameworks and platforms are still immature for agriculture, but there is a trend now to apply IoT in the agricultural sector. Duan Yan-e et al [1] proposed an IoT application to predict fertilizer application to crops using WSN. Xiangyu Hu et al. [2] developed an IoT system for the efficient use of water resources. Agri-IoT [3] analyses and processes data coming from WSN exploiting the semantic aspects. Using the Bluetooth model for communication, has its own limitations like limited range and device accommodation. Use of IoT in agriculture is mentioned by an author in a paper [4]. However, it shows a lack of interoperability which is necessary to handle large agricultural fields. Suryadevara et al. have used concepts of pervasive computing, data aggregation, etc to monitor the environmental factors using Zigbee [5]. An increase in the number of sensors is suggested by the author to improve the accuracy of the data collected. However, it might raise the issue of more power consumption as more nodes have been deployed. Real-time information about crops can be provided to farmers. Concepts of IoT, cloud computing, mobile computing [6], and Phenonet [7], a network of smart wireless sensor nodes that shares information as well as a central system can be used in smart agriculture. Yet both the papers however do not provide any interpretation of the data even though a large amount of useful data is generated. Ramesh et al. [8] had proposed a K-means technique for clustering regions based on rainfall and multiple linear regression for predicting the rainfall. They considered the East Godavari district of Andhra Pradesh data set, which includes the parameters like year, rainfall, area of sowing, and production. The advantage of this paper is proper rainfall prediction and the disadvantage of this paper is the computational cost of the K-means algorithm. Manjula et al. [9] had proposed the K-means technique for soil classification, K-nearest neighbors for simulating climate variables, and support vector machines for analyzing the different possible changes of the climate scenario. They considered the soil and climate datasets, the soil dataset includes parameters like (N, P, PH, K...).
Crop Yield Prediction using Granular SVM

Mg, S, Fe, Zn, Mn, Cu) and the climate dataset includes parameters like rainfall, humidity, minimum temperature, maximum temperature. The advantage of this paper is exact crop yield prediction and the disadvantage of this paper is less number of data attributes. Monali Paul et al. [10] had proposed a K-nearest neighbor technique for soil classification. They considered the soil dataset, which includes parameters like N, P, PH, Mg, S, Fe, Zn, Mn. The advantage of this paper is that it helps farmers to decide the land for sowing that may result in better crop production and the disadvantage of this paper is the smaller dataset used. Raine A. A et al. [11] had proposed the K-means technique for detect atmosphere pollution and soil classification and support vector machines for weather classification. They considered weather and soil datasets. The weather dataset includes parameters like humidity, temperature, precipitation, air pressure, and the soil dataset includes parameters like (N, P, PH, Mg, S, Fe, Zn, Mn, Cu). The advantage of this paper is the number of attributes considered. B. Vishnu Vardhan et al. [14] had proposed density-based clustering techniques for clustering rainfall. They considered the East Godavari district of Andhra Pradesh dataset, which includes parameters like (N, P, PH, Mg, S, Fe, Zn, Mn, Ca, Cu). Niketa Gandhi et al. [23] have proposed a K-nearest neighbor technique for classifying various crops and linear regression for analyzing rainfall, humidity. They considered the climate dataset, it includes parameters like rainfall, temperature, humidity. This approach shows the annual yield for the user and the disadvantage is less number of attributes considered. V.R.Thakare et al. [27] had proposed the Fuzzy logic technique for predicting the maximum and minimum temperature, humidity. It addresses the problem in land grading but requires an internet connection. Raju Prasad Paswan et al. [19] had proposed linear regression techniques for predict crop yield based on the good quality of clusters and neural network techniques for rainfall forecasting. Aakunuri Manjula et al. [20] had proposed a spatial data mining technique with weather datasets to predict crop yield and a multi-linear principal component analysis technique for the feature reduction phase. Ashwani Kumar et al. [21] had proposed an Agro algorithm to get quality and improved crop yields. They considered the soil dataset, which includes parameters like (N, P, PH, Mg, S, Fe, Zn, Mn, Ca, Cu).

III. SYSTEM ARCHITECTURE

A basic IoT system using an Arduino microcontroller (Aurdino Mega 2560) connects field sensors (fig. 1). The various steps include

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A. **Data Collection:** Data regarding sunshine, moisture and soil parameters are collected using various sensors. DH22 Temperature/humidity sensor is used. An electrochemical sensor system is used for soil nutrient determination. The electrochemical sensor consists of two electrodes which respond to targeted ion and transforms the reactions to detectable electrical signals. An A/D converter is used to convert the analog values to digital before providing input to the microcontroller. Ion Selective Field Effect Transistor (ISFET) can be chemically modulated and the measured voltage is related to the concentration of the targeted ion. The ability to integrate multi-ISFETs on one chip tends to detect not only N, P, K but also other nutrients such as ammonium (NH4), manganese, cobalt, sulphur, iron, calcium, and others.

B. **WiFi module:** The microcontroller retrieves data from the sensors and transmits information through the WiFi module to the system for analysis. The ESP8266 WiFi module is a self-contained SOC with an integrated TCP/IP protocol stack that facilitates the microcontroller to access the WiFi network.

C. **Cloud analysis:** The real-time data is transferred to a trained GSVM classifier that can predict the crop yield.

For the given training set $T=\{(x_1, y_1), \ldots, (x_i, y_i)\} \in (X \times Y)$, where $x_i \in X \equiv \mathbb{R}$ and $y_i \in Y \equiv \{-1, 1\}$ $(i=1,2,\ldots,l)$, a real-valued function $g(x)$ on $X \equiv \mathbb{R}^n$ was sort as the decision function $f(x)$.

$$f(n)=\text{sgn}(g(x))$$  \hspace{1cm} (1)

Consider $\xi_i$ as slack variable and $C$ as penalty coefficient. The linearly separable training set $\min \frac{1}{2} \|w\|^2 + C\sum_{i=1}^{l} \xi_i$ was obtained with the constraint in SVM

$$y_i((w \cdot x_i) + b) + \xi \geq 1, i=1,\ldots,l$$  \hspace{1cm} (2)

The hyperplane is then constructed. The decision function is then obtained as

$$f(x)=\text{sgn}(w^* \cdot x + b^*)$$  \hspace{1cm} (3)

However, SVM modeling is computationally expensive, quadratic to the number of samples and linear to the number of features. Granular SVM is more scalable.

Granular computing splits the problem into subspaces called information granules. The problem is then solved in each information granule. Being knowledge-oriented, prior knowledge is used to improve the classification. Granular computing involves:

- **Granular split:** to split a huge problem space into a sequence of granules.
- **Granule shrink:** that defines the granule size for a particular problem.

![Figure 2: GSVM for XOR](image_url)

Granular Support Vector Machines (GSVM) aims at integrating granular computing into statistical learning. GSVM extracts a sequence of information granules with granule split and/or granule shrink, and then builds SVMs on some of these granules. Prediction of GSVM is effective as it considers the local significance and global correlation among data subsets. GSVM speeds up the classification process by eliminating redundant data locally. It can convert a linear non-separable problem to a totally linear separable one. GSVM provides effective classification as it grasps inherent data distribution by a tradeoff between the local significance of a subset of data and global correlation among different subsets of data. For example, the XOR problem is not linearly separable. This is to be converted to higher dimensionality for linear separability.
Crop Yield Prediction using Granular SVM

Instead, Granular computing can be used to separate the space into two granules (subspaces at x=0) and then construct an SVM for each granule as shown in figure 2.

The steps of GSVM modeling are as follows:

a) **Granulation**: Decision Trees, Association Rules, sampling, bagging, boosting and clustering algorithms, can be used to split the original feature space into a sequence of subspaces.

b) **Classification**: Multiple information granules created in the first step are classified by classifiers. Each information granule has an SVM classifier.

c) **Aggregation**: This information is then aggregated as data fusion, decision fusion, knowledge fusion, or hybrid information fusion.

![Fig 3: Training Phase of GSVM](image)

![Fig 4: Testing Phase of GSVM](image)

During the training phase (figure 3), GSVM extracts subsets of samples from the original training dataset. Each training subset forms a granule. Data from the granule is used to train an SVM. During testing (figure 4), the data is tested with each local SVM. Results of the SVMs are aggregated by the Bayesian Sum Rule to obtain the final decision. This is done by summing the probability estimates of each local SVM for final prediction. This approach is easily parallelizable.

V. RESULTS

The hardware we used is a PC with a P4-2.8MHz CPU and 256M memory. The software used is SVM Classifier Matlab Toolbox which implements a Mat lab interface to LIBSVM. The linear, polynomial, and radial basis kernel functions were used for SVM training, after which fivefold cross-validation was used for modeling and testing, respectively. For linear SVM, regulation parameter \( C = 1 \); for RBF SVM, kernel parameter \( \gamma = 1 \) and regulation parameter \( C = 1 \). Parameters considered include PH, soil nutrients like nitrogen, phosphate, potassium, organic carbon, magnesium, sulphur, manganese, copper, iron, zinc; electrical conductivity, temperature, rainfall, humidity, sunshine, season, crop name, production.

| Crop Yield | Accuracy | Time(seconds) |
|------------|----------|---------------|
| Linear SVM | Poly SVM | RBF SVM | GSVM | Linear SVM | Poly SVM | RBF SVM | GSVM |
| Rice       | 0.96     | 0.93         | 0.97     | 0.98     | 419        | 430       | 461       | 3     |
| Wheat      | 0.82     | 0.8          | 0.75     | 0.85     | 405        | 417       | 448       | 2     |
| Maize      | 0.83     | 0.85         | 0.8      | 0.84     | 407        | 425       | 456       | 2     |

GSVM shows good accuracy along with time reduction. Future Extension is to parallelize the operations using Map Reduce programming.

VI. CONCLUSION

This paper proposes an IoT-based system (Arduino microcontroller - Aurdino Mega 2560) that retrieves data from the sensors and transmits information through the WiFi module to the system for analysis. Crop yield is predicted based on climatic, soil, and biological factors using granular support vector machines. To overcome the complexity in the dataset, the problem space is split into granules and GSVM was implemented. The overall accuracy and time for prediction has been improved using granular SVM. Experimental results demonstrate that the accuracy of GSVM is as good as a linear SVM, but time complexity is reduced.

REFERENCES

1. Duan Yan-e, “Design of Intelligent Agriculture Management Information System Based on IoT”, Fourth International Conference on Intelligent Computation Technology and Automation 2011, vol. 1 pp.1045 – 1049.
2. X. Hu and S. Qian, “IoT application system with crop growth models in facility agriculture”, 6th International Conference on Computer Sciences and Convergence Information Technology (ICCCIT), Seogwipo, Korea (South), 2011. pp. 129-133.
3. Andreas Kamlialis, Feng Gao, Frances X. Prenafeta-Boldú and Muhammad Intizar Ali, “Agri-IoT: A Semantic Framework for Internet of Things-enabled Smart Farming Applications”, IEEE World Forum on the Internet of Things (WF-IoT), Reston, VA, USA, December 2016, pp. 442-447.
4. Junyan Ma, Xingshe Zhaou, Shining Li, Zhigang Li, “Connecting Agriculture to the Internet of Things through Sensor Networks”, IEEE International Conference, 2011, pp. 184-187.
5. Sean Dieter Tejbe Kelly, Nagender Kumar Suryadevara and Subhas Chandra Mukhopadhyay, “Towards the Implementation of IoT for Environmental Condition Monitoring in Homes”, IEEE Sensors Journal,vol.13, no.10, October 2013, pp.3846-3853.
6. Hemlata Channe, Sukhesh Kothari, Dipali kadam,”Multidisciplinary model for Smart Agriculture using IoT, Sensors, Cloud-Computing, Mobile Computing & Big data Analysis”, Int.J.Computer Technology & Applications,Vol 6 (3), 2018, pp. 374-382.
7. Prem Prakash Jayaraman, Doug Palmer, Arkady Zaslavsky, Dimitrios Georgakopoulos, “Do-it-Yourself Digital Agriculture Applications with Semantically Enhanced IoT Platform”, IEEE Tenth International Conference (ISSNIP) Singapore,7-9 April 2015, pp. 1-6.
8. D Ramesh, B Vishnu Vardhan, “Data Mining Techniques and Applications to Agricultural Yield Data”, International Journal of Advanced Research in Computer and Communication Engineering Vol.2, Issue.9, September 2013, pp. 233-240.
9. E.Manjula, S.Djodiltachoumy,” Analysis of Data Mining Techniques for Agriculture Data”, International Journal of Computer Science and Engineering Communications, Vol.4, Issue.2, 2016, pp.1311-1313.
10. D Ramesh, B Vishnu Vardhan, “Analysis Of Crop Yield Prediction Using Data Mining Techniques”, International Journal of Research in Engineering and Technology, vol.04,Issue:01, Jan 2015, pp.470-474.

11. Raorane A.A, Kulkarni R.V, “Data Mining: An effective tool for yield estimation in the agricultural sector”, International Journal of Emerging Trends &Technology in Computer Science(IJETCS), vol.1, Issue 2, August 2012, pp. 220-225.

12. Rajeshkar Borat, Rahul Ombale, Sagar Ahire, Manoj Dhawade, P.S. Kulkarni, “Data Mining Technique to Predict Annual Yield for Major Crops”, International Journal for Scientific Research & Development, vol. 4, Issue 03, 2016, pp.1835-1837.

13. B. VishnuVardhan, D. Ramesh ’Density-Based Clustering Technique on Crop Yield Prediction”, International Journal of Electronics and Electrical Engineering Vol. 2, No. 1, March 2014, pp.246-250.

14. N.Gandhi, Leisa J. Armstrong and OwaizPetkar, Amiya Kumar Tripathy, “Rice Crop Yield Prediction in India using Support Vector Machines”, 13th International Joint Conference on Computer Science and Software Engineering (JCSSSE), 2016, pp.1-5.

15. Yuchun Tang, Bo Jin, Yan-Qing Zhang, “Granular Support Vector machines with association rules mining for protein homology prediction”, Artificial Intelligence in Medicine, vol. 35, Feb.2005, pp. 121-134.

16. Monali Paul, Santosh K. Vishwakarma, Ashok Verma, “Analysis of Soil Behaviour and Prediction of Crop Yield using Data Mining Approach”, International Conference on Computational Intelligence and Communication Networks, 2015, pp. 766-771

17. Narayan Balakrishnan and Dr.Govindarajan Muthukumarsamy, “Crop Production-Ensemble Machine Learning Model for Prediction”, International Journal of Computer Science and Software Engineering, Volume 5, Issue 7, July 2016, pp.32-39.

18. Naushina Farheen, R. V. Argiddi, “Annual Crop Yield Prediction and Recommend Planting of different crops by Using Data Mining Techniques”, International Journal of Innovative Research in Computer and Communication Engineering., vol. 4, Issue 10, October 2015, pp. 1-6.

19. A.T.M Shakil Ahamed, Navid Tanzeem Mahmood, Nazmul Hossain, Mohammad Tanvir Kabir, Kallal Das, Faridur Rahman, Rashidur M Rahman, “Applying Data Mining Techniques to Predict Annual Yield of Major Crops and Recommend Planting Different Crops in Bangladesh”, IEEE SNPD 2015, June 2015, pp.1-8.

20. S.Veenadhari, Dr. Bharat Misra, Dr. CD Singh, “Machine Learning Approaches for Forecasting Crop Yield based on Climatic Parameters”, International Conference on Computer Communication and Informatics (ICCCI-2014), Jan. 03 – 05, 2014.

21. Raju Prasad Paswan, Shahin Ara Begum, “Regression and Neural Networks Model for Prediction of Crop Production”, International Journal of Scientific & Engineering Research, Volume 4, Issue 9, September 2013, pp.98-108.

22. Aakunuri Manjula1 and Dr. G.Narsimha, “Crop Yield Prediction with Aid of Optimal neural network in spatial data mining: new approaches”, International Journal of Information & Computer Technology, vol. 6, no.1, 2016, pp.25-33.

23. Ashwani Kumar Kashwala, SwetaBhattacharya, “Crop yield prediction using Agro Algorithm in Hadoop”, IAACST - International Journal of Computer Science and Information Technology & Security (IJCITS), ISSN: 2249-9555 Vol. 5, No2, April 2015, pp.271-274.

24. N.Gandhi, Leisa J. Armstrong and Owaiz Petkar, Amiya Kumar Tripathy, "Predicting Rice Crop Yield Using Bayesian Networks", Intl. Conference on Advances in Computing, Communications and Informatics (ICACCI), Sept. 2016, pp.795-799.

25. Haedong Lee, Aekyung Moon, "Development of Yield Prediction System Based on Real-time Agricultural Meteorological Information", ICACT2014, 2014, pp. 1302-1305.

26. Aditya Shastry, Sanjay H A and Madhura Hegde, “A Parameter Based ANSf Model for Crop Yield Prediction“, IEEE International Advance Computing Conference (IAACC), 2015, pp.253-257

27. V.R Thakare, H.M.Baradkar, "Fuzzy System for Maximum Yield from Crops", International Journal of Applied Information Systems, 2013, pp. 4-9

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