

Crop Yield Estimation Using Deep Architectures

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ABSTRACT: Crop yield refers to measure of the yield of plants per unit area and seed generation by the plants. Monitoring and predicting the crop yield supports better agriculture in terms of quality and quantity production. Agriculture is the broadest economic sector which plays a significant role in the development of a country. In India, rice is a major crop grown and the country contributes 20% of the world rice production. In this work, a multilayer neural network model is implemented to predict the yield of the rice crop based on the statistical data available for the climatic features such as monthly rainfall, maximum temperature, minimum temperature, average temperature, irrigation and yield. Data of these features are available for 10 years from 2009-2018 for basmati and 2008-2017 for white rice. The neural network model is a four layer model. The model is trained with 80% of the data available and 20% is used to test the efficacy of the proposed model.

KEYWORDS: Neural networks, deep architectures, yield estimation, climatic features.

I. INTRODUCTION

Agriculture in India contributes to 18% of GDP. The quality and quantity of production depends on the region ecosystem which includes soil, water, air and rainfall. Government organization has generated a repository by gathering data on rainfall [9], temperature [10], irrigation [9] and yield [10, 11] of the rice crop obtained every year for a region. Based on the data available it is evident that the quality and quantity of yield is not sustained and has a major impact due to anthropogenic climate change. In this work, an attempt is being made to predict the climate change in terms of rainfall, temperature and available irrigation to assess the yield of the rice crop for the next season of harvesting.

As per the data available, rice is grown on two seasons named as Kharif and Rabi. Kharif is from June to December of every year and Rabi is from November to May. Two types of rice are considered: Basmati-PUSA breed and White rice-ACK5 breed. Basmati is majorly grown in 6 states of India while white rice is grown in all 29 states of India. The data under consideration is 6 states for basmati and 20 states for white rice accounting for 10 years and 7 months in each year. 1 feature of rainfall, 3 features of temperature and 1 feature of irrigation are considered. The dataset of basmati is 1260 and for white rice 4200.

The activation function used to build the neural network model in this work is TANSIG and PURELIN. The weights and bias values are obtained using Levenberg-Marquardt optimization algorithm.

II. RELATED WORK

Many works have been reported in literature to predict the yield using deep neural network[1], machine learning [2, 3, 4, 5], Artificial neural network[6, 7, 8] for various crops such as rice[2, 3, 6], corn[1, 4], bitter guard[5], others[7, 8]. Most of the work focuses on predicting the yield considering one factor of climate change or on a specific region of interest or plant growth.

In the existing systems various machine learning techniques have been used to estimate the yields of different varieties of food crops. Some of the techniques used were artificial neural networks, convolutional neural networks, linear regression, back propagation, SVM, DNN and many others. The machine learning techniques were applied on the different food crop varieties which included the rice crop, wheat crop, the corn yields, bitter melon yields and many others. These works done by the researchers had their own way of establishing the system that was built to identify the yields of the food crops.

The techniques involved various ideologies which included the estimation of the crop yields based on the climatic parameters which included the precipitation, temperature, evapotranspiration, humidity, soil moisture and certain other parameters that included the seed variety, fertilizers and pesticides. In this work, the focus is on the analysis of the statistical data available over a decade of time span and predicting the climatic condition and estimating or predicting

the yield of the crop. This model is required in today’s scenario to safeguard the farmers from the risk of crop/ yield failure due to change in the climatic conditions in the ecosystem.

III. METHODOLOGY

A multilayer neural network model is implemented to predict the yield of the kharif rice crop based on the statistical features. These statistical features include the period of 10 years on rainfall, temperature and irrigation for various states of India.

Description of the dataset

The dataset mainly focuses on the climatic features that have an high impact on the yields of the kharif rice crop. These features include the yield, rainfall, maximum temperature, average temperature, minimum temperature and the area of irrigation.

All the features are considered for two types of rice, the basmati whose major breed is PUSA and the white rice whose major breed is ACK5.

The basmati rice is majorly grown in 6 states of India namely Haryana, Punjab, Uttarpradesh, Uttarakhand, Himachal Pradesh, Jammu and Kashmir. Where as the white rice is grown in all 29 states of India.

The weather features rainfall, maximum, average and minimum temperature are considered for a period of seven months, June – December, as the model is based on the kharif rice crop.

The total number of years or the data period considered for the analysis of features is 10 years. 2009 – 2018 for the basmati rice and 2008 – 2017 for the white rice.

- **Rainfall:** In the considered dataset, rainfall data was collected for seven months that is from June-December. It is measured in terms of mm. The source data for rainfall is data.gov.in.
- **Temperature:** There are three limits of temperature that is being considered in the dataset: maximum, average and minimum temperature. They are obtained for seven months namely June-December. The temperatures are measured in °C. The source of data for the temperature is worldweatheronline.com.
- **Irrigation:** The total area of irrigation for various states is considered in the dataset. The area of irrigation is measured in thousand tons. The source of data for the irrigation is data.gov.in.
- **Yield:** The data of yield that is collected is measured in thousand tonnes for basmati rice and kg/hectare for the white rice. The source of data for the yield is www.apeda.gov.in for basmati rice and data.gov.in for the white rice.

A multilayer neural network model is demonstrated in figure 1 to show the details of inner layers.

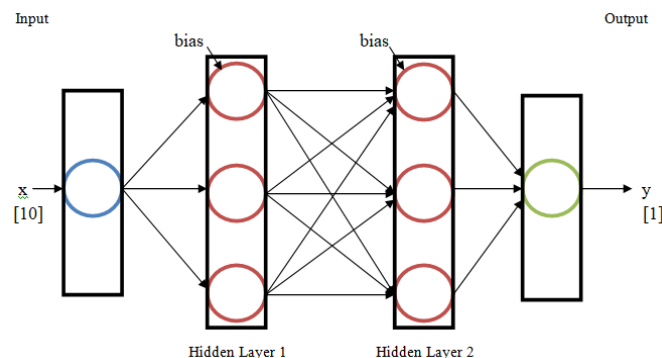


Fig. 1 Architecture of Multilayer Neural Network

The multi layer neural network is designed using the MATLAB programming tool. It is made up of two hidden layers and an output layer. The description of the multi layer neural network that is built is as follows:

- **The Input:** The total number of inputs given to the input layer for the network model built is 10.
- **Hidden Layer:** The total number of hidden layers in the composed network model is 2. The number of neurons in each hidden layer is 3, using the following formula,

$$\frac{\text{No of inputs} + \text{No of outputs}}{2} = \frac{10 + 1}{2} = 5.5$$

Then, by applying square root to the answer number of nodes is calculated.

$$\sqrt{5.5} = 2.34 = 3 \text{ Nodes}$$

- **Output Layer:** The total number of outputs in the output layer for the network model built is 1.

- **Activation Function:** In MATLAB, the activation functions are termed as the transfer functions. In this work, two activation functions are used to implement the multi layer neural network. The first function used is the TANSIG and the second one is the PURELIN.
- **Bias Value and Weights:** The weights and bias values are updated using the network training function trainlm based on the Levenberg-Marquardt optimization. The syntax for the Levenberg-Marquardt optimization in MATLAB is: net.trainFcn = 'trainlm'.

Levenberg-Marquardt Optimization Algorithm

Levenberg-Marquardt algorithm is a simple algorithm which is also termed as the damped-least squares method. The Levenberg-Marquardt algorithm is represented in a mathematical equation as follows:

$$(\mathbf{J}^t \mathbf{J} + \lambda \mathbf{I}) \delta = \mathbf{J}^t \mathbf{E}$$

\mathbf{J} = Jacobian Matrix

λ = Levenberg's damping factor

δ = Weight update vector

\mathbf{E} = Error vector

Computing the Jacobian

The Jacobian is a matrix of all of a vector-evaluated function's first order partial derivatives. In case of the multilayer neural network, it is an N-by-W matrix, where N is the number of inputs in the training set and W is the network's total number of parameters. It can be created by taking each output's partial derivatives in respect of each weight, and has the form:

$$J = \begin{bmatrix} \frac{\partial F(x_1, w)}{\partial w_1} & \dots & \frac{\partial F(x_1, w)}{\partial w_W} \\ \vdots & \ddots & \vdots \\ \frac{\partial F(x_N, w)}{\partial w_1} & \dots & \frac{\partial F(x_N, w)}{\partial w_W} \end{bmatrix}.$$

Approximating the Hessian

The Hessian generally doesn't need to be calculated for the least-squares problem. As stated earlier, the Jacobian matrix can be approximated using the formula:

$$\mathbf{H} \approx \mathbf{J}^t \mathbf{J}$$

Hence, every iteration of the learning phase (epoch) will consist of the following basic steps:

1. To compute the Jacobian by using the finite chain rule
2. To compute the error gradient equation

$$\mathbf{g} = \mathbf{J}^t \mathbf{E}$$
3. Approximating the Hessian using the cross product of Jacobian rule
 1. $\mathbf{H} = \mathbf{J}^t \mathbf{J}$
4. Equation $(\mathbf{H} + \lambda \mathbf{I}) \delta = \mathbf{g}$ is solved to find δ
5. Updating the multilayer neural network's weights \mathbf{w} using δ
6. Recalculate the sum of the squared errors using the weights that are updated
7. If the sum of the squared errors has not been reduced,
 1. Discard the new weights and increase the λ
8. Else decrease the value of λ using \mathbf{v} and the stop.

IV. EXPERIMENTAL RESULTS

In this proposed system, it is observed that the system implemented can be considered as one of the accurate and efficient methods to estimate the crop yields based on the results that are obtained. The multi layer neural network that is built using the MATLAB software depicts the accurate output for the given inputs and the set target values. By considering the inputs and the target values given that dataset is trained and the multilayer neural network is built. The trained dataset undergoes validation and testing in the performance phase in order to give the outputs of the crop yield and the respective parameters for the coming harvest season in the output layer of the designed neural network.

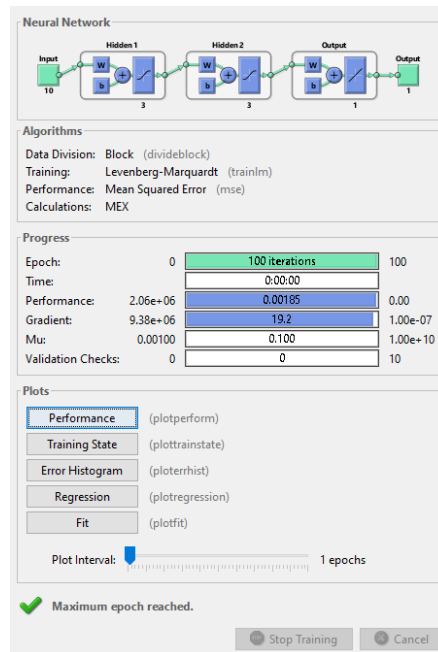


Fig. 2 NN Training Tool

The figure 2 shows the neural network training tool that is used in MATLAB to build the proposed system. It uses a method of divide block for the data division session. The training algorithm used is the Levenberg-Marquardt optimization. The fed in 100 epochs were successfully completed.



Fig. 3 Regression Analysis

The regression analysis of the multilayer neural network implemented is shown in the figure 3. It depicts the model fit based on the target and output values.

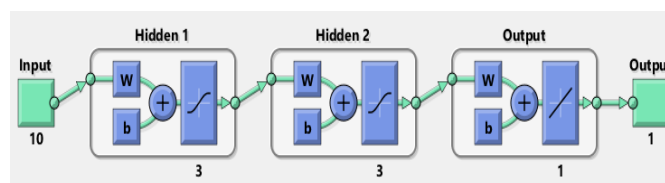


Fig. 4 Multilayer neural network model

The figure 4 shows the multilayer neural network model that is built with two hidden layers each comprising of 3 nodes.

A multilayer neural network was built using the MATLAB programming tool. The dataset was given as an input to the network and the yields and climatic parameters of the next harvest season were derived as output from the output layer.

V. CONCLUSION

In this paper, a multilayer neural network was designed and implemented which included an input, two hidden layers and an output layer. Ten inputs were given in the input layer. The hidden layer was made up of three nodes/neurons each and there was one output in the output layer.

The model has been proposed, implemented and tested for the estimation of the climatic parameters and the kharif rice crop yield.

The dataset used focuses primarily on the climatic characteristics that have a high effect on kharif rice crop yields.

The dataset was given as an input to the network and the yields and climatic parameters of the next harvest season were derived as output from the output layer. The model is trained with 80% of the data available and 20% is used to test the efficacy of the proposed model. The performance accuracy was 84%.

For the future enhancement, many more possible parameters especially the non weather parameters such as the fertilizers and pesticides can be considered as the features while predicting the crop yields using multilayer neural networks.

REFERENCES

- [1] Saeed Khaki and Lizhi Wang, "Crop Yield Prediction Using Deep Neural Networks", Journal of Frontiers, 1-16, (2019)
- [2] Pabitra Mitra, Abhijit Mukherjee, Aditi Chandra, "Machine Learning for prediction of crop yield", Indian Institute of Technology, Kharagpur, 187-194, (2019)
- [3] Rushika Ghadge, Juilee Kulkarni, Pooja More, Sachee Nene and Priya R L, "Prediction of Crop Yield using Machine Learning", IRJET, Volume: 05 Issue: 02, 2237-2239, (2018)
- [4] Andrew Crane-Droesch, "Machine learning methods for crop yield prediction and climate change impact assessment in agriculture", Environ. Res. Lett., 1-12, (2018)
- [5] Marizel B. Villanueva, Ma. Louella M. Salenga, "Bitter Melon Crop Yield Prediction using Machine Learning Algorithm", IJACSA, Vol. 9, No. 3, 1-6, (2018)
- [6] Niketa Gandhi, Owaiz Petkar, "Rice Crop Yield Prediction using Artificial Neural Networks", IEEE International conference on TIAR, 105-110, (2016)
- [7] Tirtha Ranjeet and Leisa Armstrong, "An Artificial Neural Network for Predicting Crops Yield in Nepal", Edith Cowan University, 376 -386, (2014)
- [8] Miss.Snehal S.Dahikar and Dr.Sandeep V.Rode, "Agricultural Crop Yield Prediction Using Artificial Neural Network Approach", International journal of innovative research, Vol. 2, Issue 1, 683-686, (2014)
- [9] Open Government Data Platform India, <http://www.data.gov.in>
- [10] Data for world weather forecast and weather content, <http://www.worldweatheronline.com>
- [11] The agricultural and processed food products export development authority, <http://www.apeda.gov.in>