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HYBRID CNN-LSTM MODEL: RAINFALL ANALYSIS AND PREDICTION FOR KARNATAKA REGION

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ABSTRACT

Purpose Rainfall prediction is necessary for harvesting crops throughout the year, agriculture yields crops based on the farmer's ability to work in a specific field for particular crop fertilization. This idea was not alone necessary to predict the crop's yield. Seed firms regularly screen how efficiently plant varieties grow in a particular setup. Thirdly to predict agricultural produce is critical to solving emerging concerns for food security in the phase of global climatical changes. Accurate prediction of forecasts assists farmers so they can take more economical and cost-management decisions. They also enhance the prevention of famine. This results in protecting farmers' efficiency and productivity to reduce the risks associated with environmental gain.

Design/Methodology/Approach- This paper proposes a Hybrid machine learning model for efficient prediction of rainfall, this makes a solution that is used for encoding them to create solutions abruptly. A major part of this work here is focused on generating a solution for fitness to meet the highest accuracy. This algorithm works efficiently for the given input data. This algorithm tries to meet the necessary requirements until an optimal analysis is carried out to contribute to maximum accuracy for rainfall prediction.

Findings- The performance of our proposed Hybrid Algorithm is compared with existing algorithms such as linear regression, logistic regression, and KNN. The proposed Hybrid Algorithm convolutional neural networks with LSTM (Long short-term memory model) with First-order optimization Algorithm which works along the gradient-descent algorithm based on different metrics like Accuracy, Sensitivity, Specificity, F-score, and found maximum performance.

Originality/value- This paper proposes a Hybrid algorithm CNN_LSTM along with this a first-order optimization algorithm that functions based on the gradient descent method. The results found using the proposed algorithm are plots. A comparative analysis is carried out using various results obtained to achieve high performance to solve different constraints.

Keywords- Crop Fertilization, Convolutional Neural Network (CNN), Long short-term memory model (LSTM), First-order optimization algorithm.

1. INTRODUCTION

Agriculture is the backbone of India's economy; agriculture is widely dependent on Rainfall right from the beginning of planting of seedlings to the harvesting of crops. As technology is advancing and resource utilization is improving every day. Rainfall prediction is a challenging task; India's agriculture is highly dependent on rainfall depending on the monsoon. The prediction of rainfall is into two categories i.e., long-term and short-term rainfall. India is a developing country and is heavily dependent on agriculture for the growth of the economy. Karnataka region receives maximum rainfall from July to September during the southwest monsoon season. Daily rainfall is analysed using spatial patterns and analysis of rainfall. The annual rainfall for the southwest monsoon season reaches a peak during august and deteriorates during September. The prediction concepts are essentially classified into commercial and non-commercial aspects for the businesses, improvising the sales techniques. The most significant prediction is to protect human lives from disaster management, by protecting their assets. Various climatic models were generated to deliver and analyze the climatic conditions. In this disaster prevention scheme rainfall is the essential factor in determining the amount of destruction which is received at various places. India's major population depends on agriculture, a few states depend on dry spells in agriculture, and a few states experience floods. In India where yields are sowed depending on the occurrence of rainfall therefore careful prediction strategies are necessary for rainstorm season throughout the year.

Different machine learning approaches are used to determine the accurate prediction of rainfall, predicting rainfall a few days prior to the occurrence helps in protecting one's life and assets to define various cardinal attributes. As technology is advancing each day, many strategies give rise to various predictions each day, ANN and SVM models have been broadly classified for the analysis of rainfall prediction. ANN model reduces empirical risk. This model potentially approximates the function without any appropriate consequence about the input. Many deep learning techniques have the ability to predict rainfall with deep learning language of natural phenomenon. However, this suffers from various issues like overfitting, which results in deteriorating performance. Various optimization strategies as well were proposed to minimize empirical risk techniques. When the analysis was done using SVM it gave better results in comparison with ANN. While analysing various machine learning algorithms, each algorithm performs in a different manner when compared to one model. Adaboost algorithm performs better than the other neural networks. Deciding on significant features is an essential task for predicting rainfall, algorithms, and computational performance depending on input attributes. Feature selection is an important technique to enhance the interpretation of models by selection methods like the random forest, SVM, KNN, and ANN. The performance evaluation is carried out through various performance metrics like F1- score, and accuracy.

1.1 Motivation and contribution to research work:

The purpose of this study is to develop a hybrid algorithm for effective rainfall prediction and carry out a comparative analysis of different existing algorithms to determine a method that is capable of accurate prediction of rainfall. The data collected is from NASA for the Karnataka region based on their regional occurrence using the latitude and longitudinal capacity. The data is pre-processed and cleaned before it is fed into the Hybrid CNN-LSTM model for analysis. The classifier used here is the CNN-LSTM classifier, to enhance the performance of the classifier first-order optimization algorithm is used. The effectiveness of our proposed model is analyzed using different performance metrics.

The main contribution is listed below:

- For rainfall analysis and prediction, a hybrid CNN-LSTM model is used, which is also known as a CNN-LSTM classifier.
- To improvise the CNN-LSTM classifier, a first-order optimization algorithm is presented.
- The performance of the proposed approach is evaluated on the basis of
- Besides this the performance of the proposed model is compared with logistic regression and linear regression.

The rest of the paper is organized as follows, in Section 2 a thorough literature survey is carried out and the techniques used in this paper are given in Section 3. The proposed method is explained in detail in section 4 and the test results are analyzed in Section 5. The results are given in Section 6.

2. LITERATURE SURVEY

In [1] prediction of rainfall to provide awareness to people, many machine learning algorithms like ARIMA model, ANN, LR, and SVM. Deep learning techniques like MLP and Auto-encoders. The auto encoder is used to extract information on all non-linear features using MLP. The performance is evaluated to estimate issues faced by the measurement of precipitation to change the property spatially and locally. In all types of weather scenarios, a model is developed to incorporate changes in climate.

Rainfall prediction for multiple datasets, the input dataset consists of multiple parameters like accuracy, correlation, and MSE. The proposed method is used to predict rainfall using supervised and unsupervised learning methods. Several rainfall patterns were recorded all over India using machine learning algorithms, the data is collected from the government for twenty years using neural networks to increase the accuracy of different layers. To enhance the accuracy of the model the neurons in each layer increase the accuracy of prediction. To get good results in comparison with other machine learning algorithms. When more data is added to the dataset the machine learning techniques give better results and performance.

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The machine learning algorithms [2] like ARIMA, and SARIMA for the purpose of time-series analysis, a comparative study has been carried out between neural networks and Deep learning models. A model to predict different climatic conditions traversing the Indian sub-continent using Data analysis and machine learning approaches. The proposed system [3] uses a feed-forward neural system that uses a component of parameter x information. The atmospheric conditions like temperature, humidity, etc. to fit a model to utilize certain parameters. the precision is proposed for a model that is expanded at 70%.

A heuristic approach to predict rainfall [4] by using machine-learning techniques is needed to analyze different categories of data using linear regression method for predicting rainfall which becomes a challenging task using ANN, SVM, and Logistic Regression. The potential strategy [5] used here is to predict the unknown value of a particular season with a known value. For the two seasons RABI and Kharif if considered, linear regression is applied on this which makes sense to predict the yield of crops based on rainfall.

An ANN model [6] is developed to forecast significant moisture on the surface. The neural networks produce a single hourly rate to enhance pattern recognition. Natural hazards occur commonly in Indian Himalayas; rainfall forecasting helps to determine the conditions which are responsible for the occurrence. The proposed system [7] here improvises the performance comparison measures using different machine learning algorithms. The proposed model is compared with various machine learning algorithms for the prediction of the occurrence of natural slides. These models are validated based on independent data; normalization is essential to enhance the predictive accuracy for the occurrence of landslides in advance.

Optimization algorithms [8] are used to train the loss function using Linear Regression, evaluating the models for performance using MAE, and RMSE. Machine Learning Algorithm to forecast rainfall by LSTM approach. Three months of rainfall [9] is predicted using three years of data. Rainfall with the past three years of data is analysed to produce an optimal forecast, to predict rainfall including landslides. Prediction of precipitation is beneficial to prevent floods to save people's lives and property. Regression and Decision tree algorithm in which Fuzzy logic process [10] data handling to frequently analyse computation methods for weather forecasting. Weight training is used to decrease the error function of various neural networks. SVM accumulates the experience of the estimated memory of the forecasted model for generalization in comparison with NN methods. Nonlinear relationships [11] of rainfall datasets learn from previous data. ANN approach makes the best solution for all the approaches available. Improvising the architecture for various weather scenarios, to develop small changes in climate for future data.

In [12] a hybrid neural network approach is developed which estimates the statistical performance metrics that have been proposed to predict rainfall on various temperature-related conditions a hybrid NN model is proposed. In the first step which involves clustering of data, a NN is employed for performance evaluation using various metrics. Feature selection improves the performance [13] of any hybrid classifier which effectively predicts rainfall strategy. Feature selection results have been improved to attain an accuracy of 78.70%. feature selection mechanism plays a key role in an accurate model.

To develop a hybrid rainfall forecasting model [14] a combination of neural networks along with optimization algorithms, the expert knowledge here is used to combine various network techniques integrated with neural networks to achieve a greater result. The [15] expert data system tries to create a hybrid environment combined to get intelligent applications, which outperform the model. Neural networks [16] are used for applications to expertise in domain knowledge. Out of the three models developed data mining and neural network hybrid model predicts rainfall with high accuracy for different horizons. A precise forecast of rainfall is carried out for long-term rainfall, several studies have been carried out to predict rainfall for various zones. Many machine learning SoftMax computing algorithms [17] have been used for the purpose of predicting rainfall. MLP- WOA optimization algorithm is been used to predict annual rainfall for various MLPs. These models were developed by taking three input variables of long-term rainfall. Usually, 70% of data is used for training and 30 %of data is used for testing purposes. The accurateness of a model is developed and examined using RMSE error, and correlation coefficient. The analysis of results shows that the inputs are presented for accurate forecasting methods.

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A hybrid [21] Deep learning technique is used to deal with complex systems, a one-D CNN network, and MLP for multi-step ahead for daily prediction of rainfall associated with variation in rainfall. The proposed deep learning approach is to establish an effective deep learning approach to augment the quality of rainfall prediction. A proposed system helps in analyzing effective DL approaches of different locations for different climatic regions. Various strategies are used for the accurate prediction of rainfall. The machine learning techniques used have the potential of being harnessed. In this paper, the LSTM model [22] along with RNN to predict rainfall is used as a standard dataset for training and testing the deployed model. The time-series data is pre-processed to enhance predictive analysis. The data which is pre-processed is fed into the ANN model which is implemented for benchmarking the LSTM model. The parameters considered improve the performance and accuracy of the model by various performance evaluation metrics like learning epochs, hidden layer neurons, and RMSE values.

Predicting rainfall in a hilly region [23] is a challenging task due to the absence of a rain gauge and uncertainty in rainfall data. These hilly regions are susceptible to floods and droughts cloud burst etc. understanding the precipitation of these regions are required to mitigate the plans and implement them accordingly. TRMM data is used for the purpose of runoff simulation for ground measurements to estimate rainfall, the data could be used for runoff simulation where no gauge station is used for early investigation purposes. Geo-spatial tools are used as promising tools for satellite-based rainfall estimation mechanisms.

The SARIMA model [24] is used for time-series estimation of data to predict rainfall using a season correlogram which is assessed. The output of this SARIMA model is given as an RMSE value. The ARIMA model accurately forecasts rainfall and works as an effective model for rainfall prediction without any error. The time-series data is recorded to solve issues such as floods, drought, and other problems which are faced by farmers. Statistical analysis is carried out on various ARIMA models to determine the performance which is evaluated using MSE and RMSE models. This clearly shows that the ARIMA model [25] forecasts the rainfall with less error and forecasts the rainfall in upcoming years. The average rainfall analysis annually, for the purpose of agriculture planning, the policy makers manage the irrigation department to analyze and predict the trend of rainfall analysis for time-series data using statistics. The data is segmented into four seasons for the purpose of classification to find climatic variations for the cultivation of crops, the daily weekly, and monthly rainfall pattern, the texture of the soil, and the water retention capacity analysed.

3. PROPOSED METHOD

The objectives of the proposed work are as follows.

1. Past 10 years of data are collected from NASA for the Karnataka region based on its longitudinal and latitudinal placement of coordinates.
2. Data cleaning is carried out by removing redundant and ambiguous data using Data Pre-processing.
3. Evaluating the performance of our proposed model with various performance metrics.
4. Data analysis is carried out through graph depiction.

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3.1 CNN Algorithm

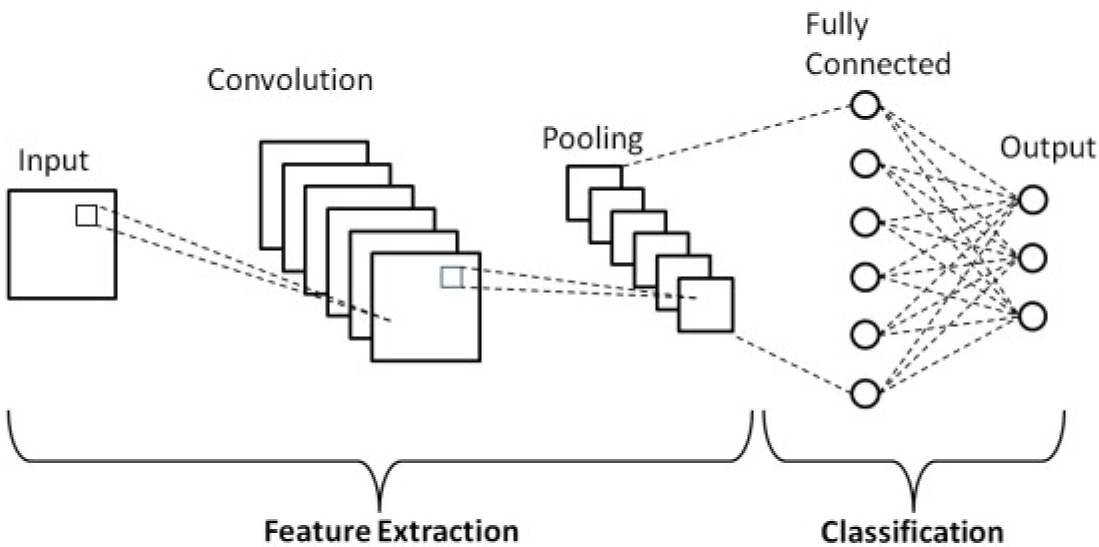

Figure 1: The Architecture Of Convolutional Neural Network

A convolutional-neural network is an algorithm based on a deep-learning framework that takes an input image, allocates importance to different attributes in the input image, and is necessarily able to differentiate from each other. The pre-processing is essential and much lower in comparison with various other classification algorithms. In traditional methods, the CNN layers have the ability to learn from these filters. The architecture of CNN resembles the connectivity of patterns of neurons similar to the brain architecture. This architecture is inspired by the visual cortex, individual neuron patterns in the human brain which respond to a stimulus in a restricted region known as the receptive field. A collection of these fields overlap and encompasses the entire area.

3.2 LSTM Network:

An LSTM is an artificial neural network in a deep learning framework. Unlike other networks, LSTM has feedback networks. LSTM is capable of performing functions such as handwriting, machine translation, speech recognition, video games, and the Health sector. LSTM cells are used for classification purposes processing and prediction-making in time-series data. LSTM units are capable of solving the gradient problem. LSTM networks suffer from gradient problems.

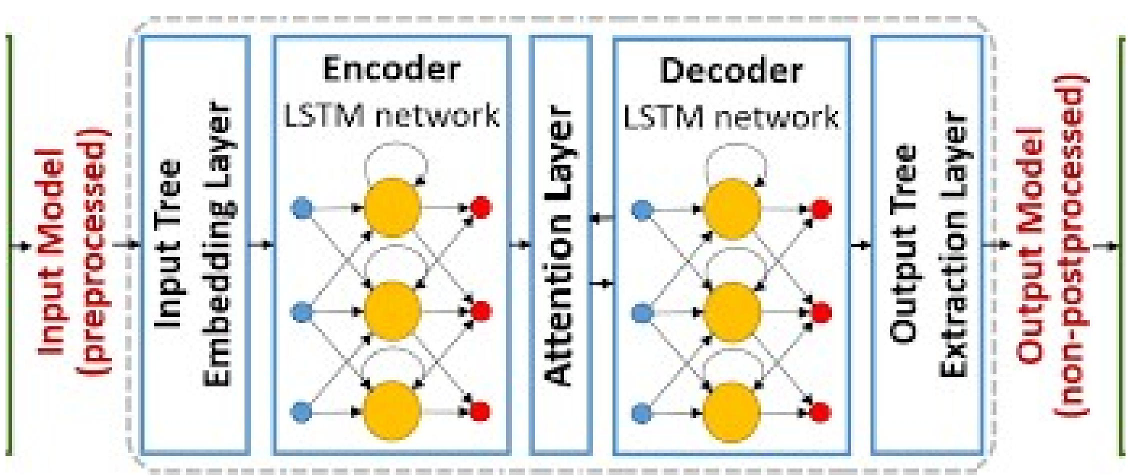

Figure 2: The Architecture Of The LSTM Network

3.3 CNN-LSTM Hybrid Classifier Model

In the CNN-LSTM hybrid algorithm, the convolutional layers in the CNN algorithm are used to extract features through the input data whereas the LSTM algorithm is used to analyze short-term and long-term dependencies.

A. **Pre-processing**: the raw dataset is acquired on a per-day basis for the previous 10 years. The analysis of features is carried out to obtain essential attributes from the data. The Pre-processing is carried out on the raw data collected to remove unwanted values, remove redundancy in the data collection, and clean the data thoroughly to be fed into the model for training.

B. **CNN-LSTM hybrid classifier Model:**

A common approach is to adopt a parameter optimization of a neural network to work in different combinations to estimate the performance of a network. This classifier involves a high computational analysis of a huge number of training parameters. The architecture discussed below figure to implement a Feature extraction method where kernels are present in the lower layers, which are depreciated by a constant as the progress is downwards. This structure reduces overfitting and decreases the total number of parameters used for training.

In the sequence we are using three different LSTM layers, the sequence of the hidden states whereas in the LSTM layer the false network is used to output the hidden state as the final step. The number of layers in the output varies between different neurons in the output layer. The input data is split into 70% training and 30% testing. Calculate the RMSE value, and evaluation is carried out on different performance metrics. Initially, the training data is loaded, and then the validation data is loaded, and then the training is initialized. Once each epoch is finished the loss for validation is checked to see if its value is depreciated. If the value is decreased the epochs are incremented. If the value is not decreasing, then the learning rate is depreciated and epochs are incremented. The training process is stopped once the epoch reaches 100 values. To save the best model for predicting and evaluating the test data for avoiding overfitting.

3.4 First-Order Optimization Algorithm

The widely used deep-learning-based optimization algorithm is the gradient descent algorithm. To find a local minimum of a gradient descent function by taking one step proportional to the negative of the gradient at the function at a particular point. Starting from the 0th parameter for optimization as well as iteration given as

$$a_{x+1} = a_x - \delta_x((\nabla j)(a_x))^y$$

Here δ_x is the learning,

The problem associated with gradient descent is that if it is progressing slowly then it is termed a (Vanishing gradient), if the gradient descent fails to converge then it is termed an Exploding gradient. The gradient methods alter the step-size iterations on the basis of the properties of a function.

4. PROPOSED MODEL FOR RAINFALL ANALYSIS AND RAINFALL PREDICTION

The main aim of this work is to analyze the rainfall and predict the rainfall for the Karnataka region by hybrid CNN-LSTM classifier. The most challenging task is the accurate prediction of rainfall. The proposed architecture is depicted in figure 3. The proposed model is classified into two phases, in the first phase a thorough analysis of previous years' rainfall on a day basis, and in the second phase, we perform the prediction of rainfall by coming two algorithms known as CNN-LSTM classifier to enhance the performance of prediction of rainfall. Before the data is fed into the classifier pre-processing is done, the CNN is responsible for the analysis of the pre-processed data, whereas the hybrid CNN-LSTM model is responsible for the prediction. CNN algorithm is used because it considers a smaller number of parameters in the network and has less chance of overfitting. LSTM is used here because of its nature of learning and prediction in sequence. The first-order algorithm is used here for optimization against the gradient descent method.

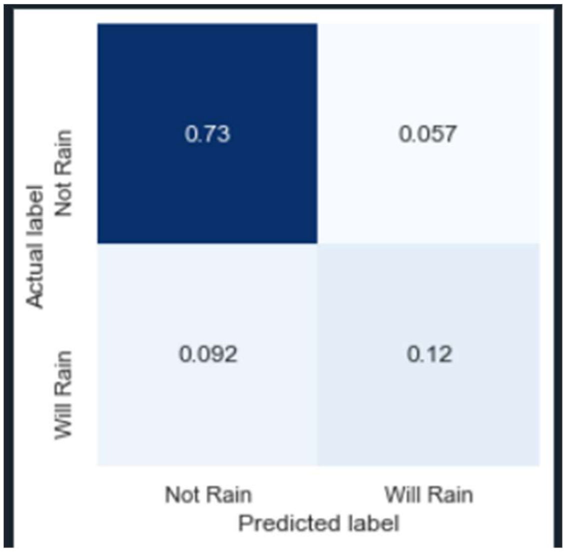

Figure 3: Confusion Matrix Plotted For The Occurrence Of Rain

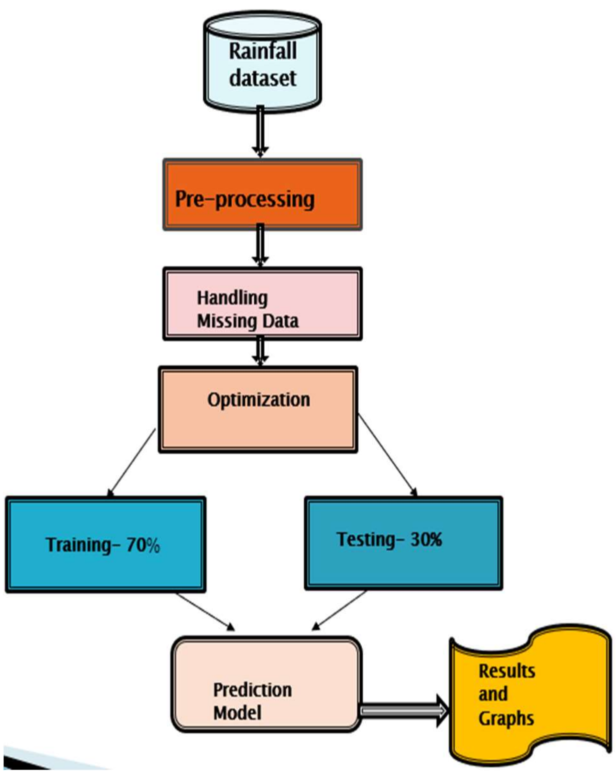

Figure 4: System Architecture Of Proposed Model

4.1 Prediction Using the Hybrid Classifier

Once the pre-processing is done, data analysis is done using the CNN algorithm, after this the prediction is carried out using the Hybrid CNN-LSTM model, which is integrated with CNN and LSTM. To enhance the performance of the classifier we perform optimization using a First-order optimization algorithm. The architecture of the CNN-LSTM hybrid model is depicted in figure 4.

Algorithm 1

Step 1: Initially, the cleaned data is fed as the input to the CNN model. In the CNN different attributes of the input given are determined, next step is pooling where the important features are selected from the image, the input is too huge to be handled by the system, and pooling reduces the size of the input without loss of essential attributes. In the next step of flattening a 3D size of data is converted into 1D further for classification purposes.

Step 2: The output of the CNN layer is fed to the LSTM networks, where the cell state is responsible to give the memory to the LSTM so that it could remember the past. The gates in LSTM are responsible for the sigmoid function where the value is given between 0 and 1.

Step 3: 0 here indicates that it has no rainfall occurrence whereas 1 indicates the possibility of occurrence of rainfall.

The below equation for the gates in LSTM is given as:

$$R_a = \boldsymbol{\tau}(\boldsymbol{U_i}[\boldsymbol{x_{a-1}}, \boldsymbol{v_a}] + \boldsymbol{y_i})$$

$$S_a = \boldsymbol{\tau}(\boldsymbol{U_s}[\boldsymbol{x_{a-1}}, \boldsymbol{v_a}] + \boldsymbol{y_s})$$

$$O_a = \boldsymbol{\tau}(\boldsymbol{U_o}[\boldsymbol{x_{a-1}}, \boldsymbol{v_a}] + \boldsymbol{y_o})$$

R_a represents the input

S_a represents the forget gate

O_a represents the output gate

Step 4: The output of the hybrid model is transferred to the optimization model, here the optimization is carried out using the first-order optimization algorithm against the gradient descent, which optimizes the weight values associated with it.

Step 5: The results and graphs are plotted against the weight optimization algorithm, the determination of rainfall data for analysis purposes.

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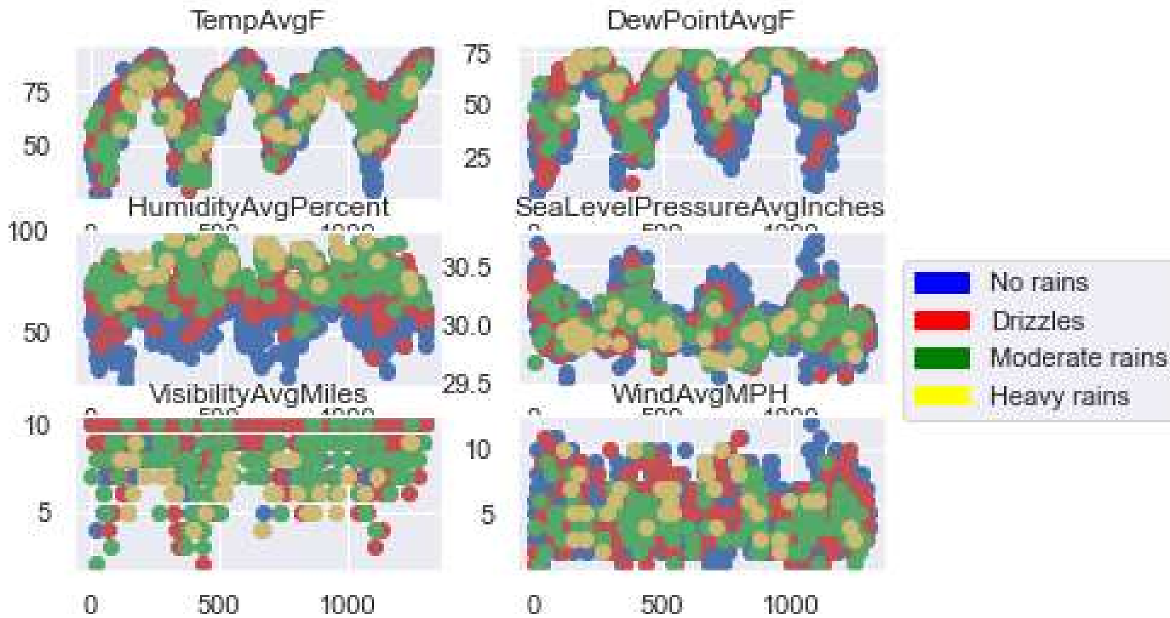

Figure 5: Rainfall Analysis Depiction For The Parameters Considered

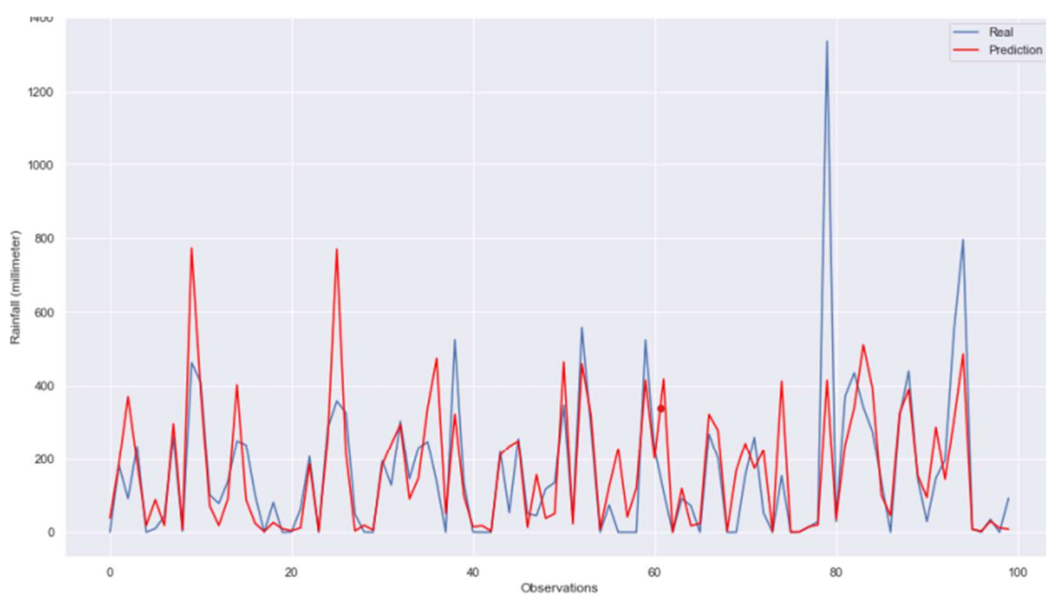

Figure 6: Rainfall Prediction Using The Hybrid CNN-LSTM Classifier

5. RESULTS AND DISCUSSION:

The result obtained from the proposed rainfall prediction system is discussed. This project requires a framework of Intel core i5 processor, on a system with 6GB RAM in the windows operating system. Simulation is carried out using the Spyder framework.

5.1 Dataset Details

The Data is gathered from the NASA website for the Karnataka region based on its latitudinal and longitudinal positioning of the ordinates. Data is collected for the past 20 years for all the districts of the Karnataka region. The parameters considered here are Pressure, Wind-gust, Humidity, Minimum-Temperature, Maximum-Temperature, Date, Location, and Sunshine. The analysis is done on the

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previous 20 years' dataset and the prediction is done for a specific timestamp.

5.2 Comparison analysis of rainfall prediction:

The effectiveness of the proposed model is calculated, and the hybrid model is compared with various other methods for prediction purposes, that as linear regression and logistic regression. In the above figure, the efficiency of the above system is calculated using the accuracy, the accuracy of the hybrid model is compared with that of other methods like linear regression and logistic regression as well as KNN.

5.2.1 Performance metrics:

The performance of the system is calculated using performance metrics that as precision, recall, f1-score, and support is calculated. The testing phase gives the value of root mean square efficiency denoted as (RMSE).

- **Accuracy**: Accuracy is the most intuitive performance measure and it is simply a ratio of correctly predicted observations to the total observations.
- **Precision** - Precision is the ratio of correctly predicted positive observations to the total predicted positive observations.
- **Recall -** Recall is the ratio of correctly predicted positive observations to all observations in the actual class.
- **F1 score** – The F1 Score is the weighted average of Precision and Recall. Therefore, this score takes both false positives and false negatives into account.

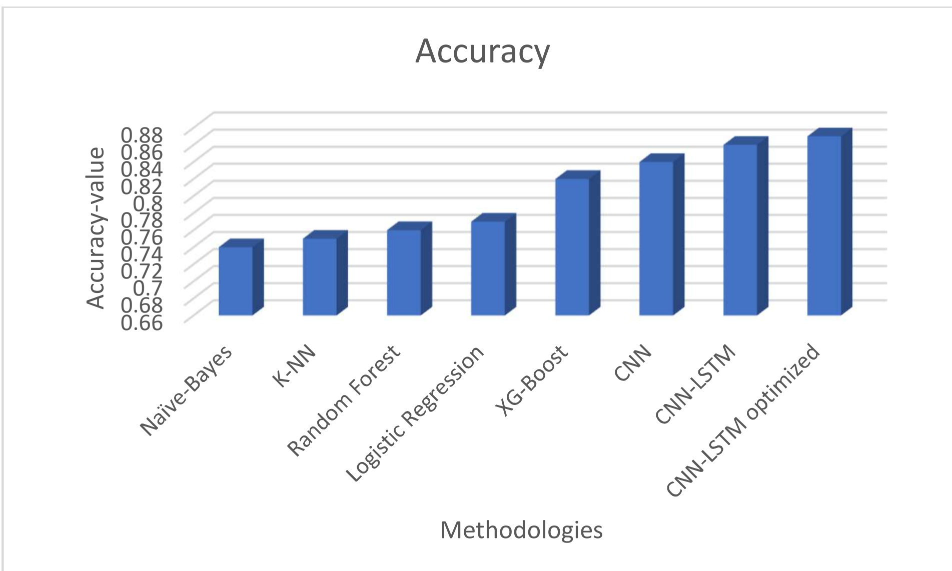

Figure 7: Accuracy Comparison Of Proposed Algorithm With Existing Algorithms

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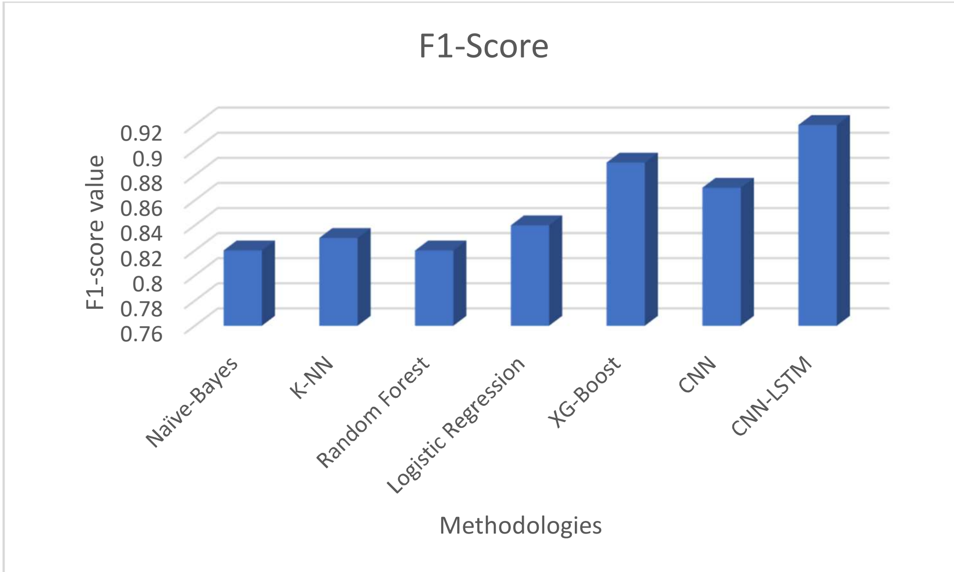

Figure 8: F1-Score Comparison Of The Proposed Algorithm With Existing Algorithms

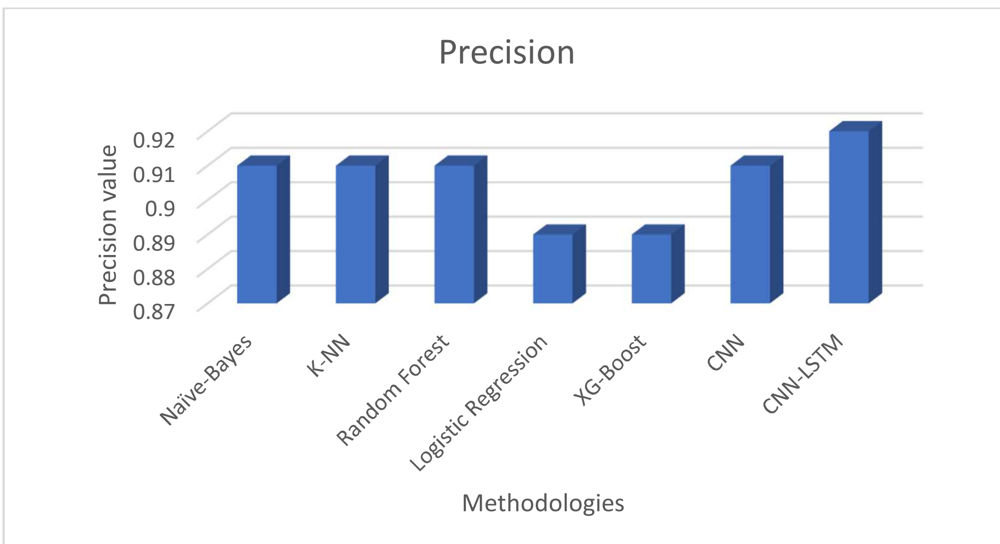

Figure 9: Precision Metric Comparison Of Proposed Algorithm With Existing Algorithms

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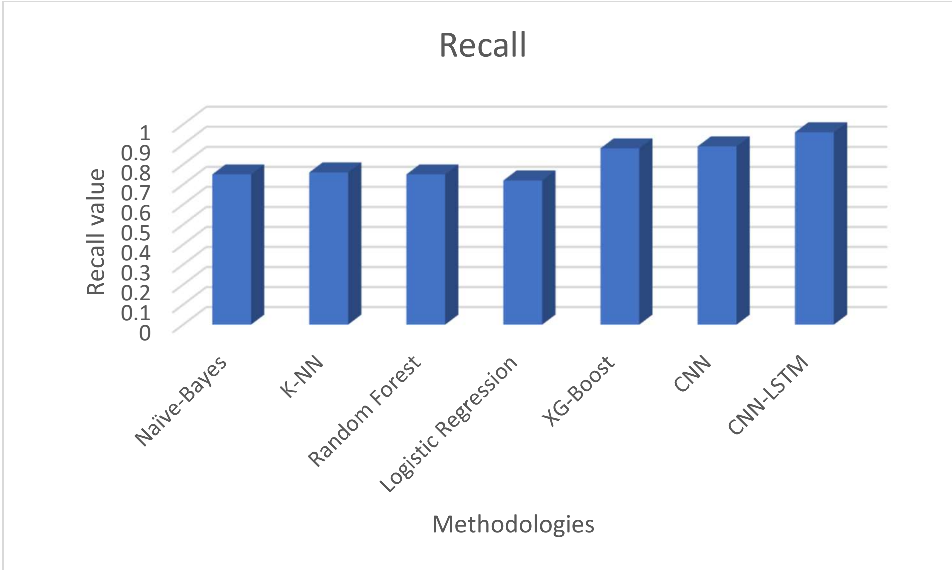

Figure 10: Recall Metric Comparison Of Proposed Algorithm With Existing Algorithms

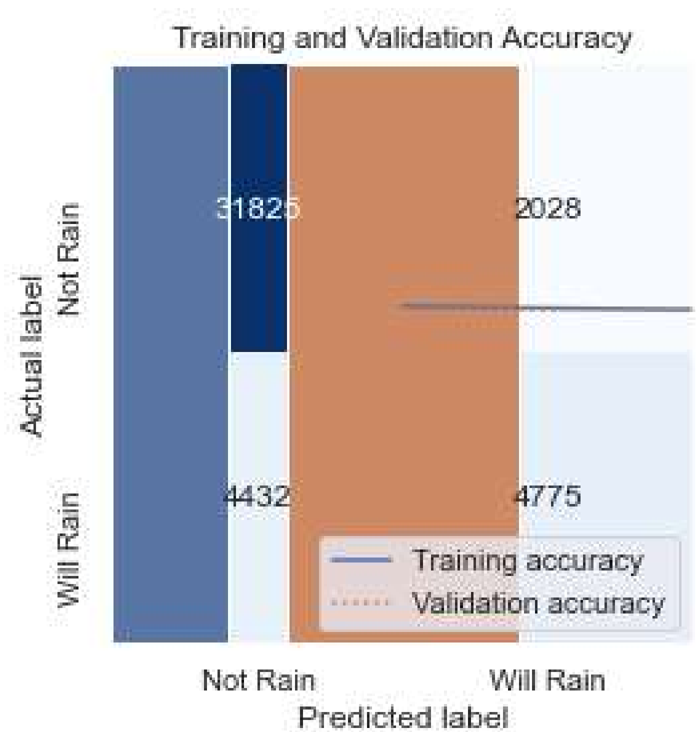

Figure 11: Rainfall Prediction For Oversampling Of Imbalanced Dataset

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6. CONCLUSION:

Rainfall prediction is a challenging task; as a result, an efficient model is required. The data analysis in the initial stage for Karnataka region based on its coordinates the data is collected and an efficient CNN-LSTM-based rainfall prediction classifier is proposed. Convolutional neural networks (CNN) and long short-term memory networks are integrated into this system to form the CNN-LSTM classifier. The proposed approach here overcomes the difficulties associated with the individual CNN and LSTM framework which has enhanced the accuracy of the system. This method achieves an accuracy of 86.2%. This accuracy is further enhanced after optimization approximately to 87.3%.

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All authors have contributed equally.

REFERENCES:

[1] K. Chen, K. Chen, Q. Wang, Z. He, J. Hu, and J. He, ''Short-term load forecasting with deep residual networks,'' IEEE Trans. Smart Grid, vol. 10, no. 4, pp. 3943–3952, Jul. 2019, doi: 10.1109/TSG.2018.2844307.

[2] G. Dudek, ''Pattern-based local linear regression models for shortterm load forecasting,'' Electr. Power Syst. Res., vol. 130, pp. 139–147, Jan. 2016.

[3] J. Zhao, L. Li, Z. Xu, X. Wang, H. Wang, and X. Shao, ''Full-scale distribution system topology identification using Markov random field,'' IEEE Trans. Smart Grid, vol. 11, no. 6, pp. 4714–4726, Nov. 2020, doi: 10. 1109/TSG.2020.2995164.

[4] Y. Wang, Q. Chen, N. Zhang, and Y. Wang, ''Conditional residual modeling for probabilistic load forecasting,'' IEEE Trans. Power Syst., vol. 33, no. 6, pp. 7327–7330, Nov. 2018, doi:10.1109/TPWRS.2018.2868167.

[5] Tayde, Praful S., Balkrishna K. Patil, and Rajesh A. Auti. "Applying Data Mining Technique to Predict Annual Yield of Major Crops." Int. J 2, no. 2 (2017).

[6] Ramesh, D., and B. Vishnu Vardhan. "Analysis of crop yield prediction using data mining techniques." International Journal of research in engineering and technology 4, no. 1 (2015): 47-473.

[7] Medar, Ramesh A., and Vijay S. Rajpurohit. "A survey on data mining techniques for crop yield prediction." International Journal of Advance Research in Computer Science and Management Studies 2, no. 9 (2014): 59-64.

[8] (2018). National Oceanic and Atmospheric Administration, Weather Related Fatality and Injury Statistics. [Online]. Available: http://www.nws.noaa.gov/om/hazstats.shtml

[9] D. Shome, S. Marx, K. Appelt, P. Arora, and R. Balstad, "The psychology of climate change communication: A guide for scientists, journalists, educators, political aides, and the interested public," Nat. Geographic, Center Res. Environ. Decisions, New York, NY, USA, Tech. Rep., 2009, p. 54

[10] Core Writing Team, R. K. Pachauri, and L. A. Meyer, Eds.,Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, document, IPCC, Geneva, Switzerland, 2014, p. 151.

[11] Annual Report, 2017, Ministry Earth Sci., New Delhi, India, 2017.

[12] S. Dash and R. Maity, ''Temporal evolution of precipitation-based climate change indices across India: Contrast between pre- and post-1975 features,'' Theor. Appl. Climatol., vol. 138, nos. 3–4, pp. 1667–1678, Nov. 2019.

[13] Chaw Chaw Khaing and Thin Lai Lai Thein, "Prediction of Rainfall Based on Deep Learning and Internet of Things to Prevent Landslide", IEEE 9th Global Conference on Consumer Electronics (GCCE), 2020.

[14] Xiaobo Zhang, Sachi Nandan Mohanty, et al., "Annual and Non-Monsoon Rainfall Prediction Modelling Using SVR-MLP: An Empirical Study from Odisha", IEEE, Volume: 8, DOI: 10.1109/ACCESS.2020.2972435, 2020.

[15] Mohd Imran Khan and Rajib Maity, "Hybrid Deep Learning Approach for Multi-Step-Ahead Daily Rainfall Prediction Using GCM Simulations", IEEE, Volume: 8, DOI: 10.1109/ACCESS.2020.2980977, 2020.

[16] Guohui Li, Wanni Chang and Hong Yang, "A Novel Combined Prediction Model for Monthly Mean Precipitation with Error Correction Strategy", IEEE, Volume: 8, DOI: 10.1109/ACCESS.2020.3013354, 2020.

[17] J Park, and I Sandberg, (1991) Universal approximation using radial basis function networks. Neural Computation, 3 (2), 246-257. [5] T. Kohonen, (1990), The self-organizing map. Proceedings of IEEE, 78(9), 1464-1478.

[18] W. Patterson Dan, (1996), Artificial Neural Networks: Theory and Applications, Prentice Hall.
[19] G.E.P. Box & G.M. Jenkins, 1970. Time Series Analysis, Forecasting and Control, Holden-Day, CA, San Francisco.
[20] M.J.C., Hu, Application of ADALINE system to weather forecasting,Technical Report, Stanford Electron, 1964.
[21] D.F. Cook and M. L. Wolfe, "A back-propagation neural network to predict average air temperatures", AI Applications, 5, 40-46, 1991.
[22] D.W. McCann, "A Neural Network Short-Term Forecast of Significant Thunderstorms", Weather and Forecasting, 7, 525-534, doi: 10.1175/1520-0434, 1992.
[23] Thirumalai, Chandrasegar, et al. "Heuristic prediction of rainfall using machine learning techniques." 2017 International Conference on Trends in Electronics and Informatics (ICEI). IEEE, 2017.
[24] Geetha, A., and G. M. Nasira. "Data mining for meteorological applications: Decision trees for modeling rainfall prediction." 2014 IEEE International Conference on Computational Intelligence and Computing Research. IEEE, 2014
[25] Parmar, Aakash, Kinjal Mistree, and Mithila Sompura. "Machine learning techniques for rainfall prediction: A review." 2017 International Conference on Innovations in information Embedded and Communication Systems. 2017.
[26] Dash, Yajnaseni, Saroj K. Mishra, and Bijaya K. Panigrahi. "Rainfall prediction for the Kerala state of India using artificial intelligence approaches." Computers & Electrical Engineering 70 (2018): 66-73.
[27] Singh, Gurpreet, and Deepak Kumar. "Hybrid Prediction Models for Rainfall Forecasting." 2019 9th International Conference on Cloud Computing, Data Science & Engineering (Confluence). IEEE, 2019.
[28] Kar, Kaveri, Neelima Thakur, and Prerika Sanghvi. "Prediction of Rainfall Using Fuzzy Dataset." (2019).
[29] Nayak, D. R., Mahapatra, A., & Mishra, P. (2013). A survey on rainfall prediction using artificial neural network. International Journal of Computer Applications, 72(16).
[30] Dubey, A. D. (2015). Artificial neural network models for rainfall prediction in Pondicherry. International Journal of Computer Applications, 120(3).