A thorough analysis of Rainfall Prediction methods through Machine Learning

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Abstract: **- Rainfall in the Indian Subcontinent has been highly useful to the farmers as it has been extensively used for the purpose of irrigation of the crops and the recharging of the groundwater levels. Therefore, it can be understood that Rainfall is an important event such that there is a need to develop a system that can be able to track and accurately predict rainfall. Rainfall prediction is highly important nowadays owing to the fact that the monsoon season has been highly irregular in recent years. This has led to the loss of a large number of agricultural products to the farmer due to untimely rains. This is highly undesirable and can lead to an already indebted farmer to go further into debt. Therefore, the application of Machine Learning can be a boon in this scenario, due to the fact that this paradigm can analyze and store previous data regarding the rain using which the algorithm would predict the rainfall with utmost accuracy. This publication has analyzed the previous works based on Rainfall prediction, which has helped immensely in formulating a methodology based on the Hidden Markov Model and is classified using Fuzzy Classification.**

I. INTRODUCTION

Rainfall is one of the most useful natural phenomena. Rain is usually highly useful for the irrigation of the crops that can help feed a large populous. Rainfall also serves the purpose of recharging and storing groundwater levels. This is a highly crucial aspect as most of the residents usually depend upon the supply of groundwater for their nourishment. Rainfall fills the wells back up in addition to providing the non-perennial rivers with abundant water. Rainfall is also a source of the tremendous power of water that can be unleashed when there is excessive downpour that can wash off weak houses and uproot mighty trees with the powerful flow of water.

In India, the monsoon season is the time of the year for the regular and almost constant barrage of rainfall. This is due to the moisture-laden South West Monsoon winds making contact with the Indian subcontinent. For a few months, the rainfall can be highly frequent with increasing amounts of precipitation. Monsoons are the time of the year that is marked by heavy rainfall all across the country and has been fairly regular over the years. This is how many farmers plan and sow their seeds and wait for the rain to irrigate their fields. This is usually not suited as most of the recent years, the monsoon has been highly infrequent.

The problem lies in the accurate prediction of rainfall. This is a highly complex problem that requires the consideration of a large number of parameters. The parameters control the onset of rainfall which is a highly dynamic process. there are a large number of atmospheric parameters that come into play when initiating rainfall. One such parameter is the atmospheric water vapor content. The atmospheric measure of the Water vapor content can be highly useful as it defines the amount of Precipitable Water Vapor in that particular column of atmosphere. This gives an estimate of the rainfall that can occur in that particular area quite accurately.

The Perceptible Water Vapor can be calculated through the use of various different techniques, such as Microwave Radiometers, Radiosondes and instruments used on a satellite for the purpose of weather data collection. Microwave radiometers are not used regularly due to their cost and the maintenance is quite high. The Radiometers have also been known to be very limited in its application as they can't be used in an event of rainfall as they are unable to take accurate readings such as Perceptible Water Vapor in the rain. The Radiosondes are highly sensitive and are usually not deployed in inclement weather. In the case of light rain, the radiosondes can be deployed only twice in a day to collect the various readings regarding the PWV.

Even in light rain, the Radiosondes are not accurate enough to provide the Perceptible Water Vapor from being detected precisely. Therefore, it can be concluded that the radiosondes can operate optimally and accurately in a scenario where there is absolutely no rainfall. This is highly limiting and can be pretty much useless in an application in the Indian subcontinent, due to its frequent rains. Another method is to utilize satellite imaging and determining the Perceptible Water Vapor (PWV) through tracking and satellite-based retrieval. But this technique is also riddled with its own drawbacks due to a poor temporal resolution which leads to less than par results.

Another valuable technique for the prediction of rainfall is the use of GPS monitoring satellites for the purpose of Perceptible Water Vapour content in the atmosphere. There has been a lot of research in this direction that has been utilized for the prediction of rainfall in a lot of areas. One of the most popular use was in the country of Japan for the prediction of heavy rainfall. The GPS system is a highly accurate representation of the water vapor in the atmosphere and can classify various conditions based on the water vapor content, such as heavy or severe rainfall and mild or moderate rainfall.

Along with the moisture content of the air, there is a large list of parameters that can dynamically alter the state of the environment and cause rainfall. These factors play a large role in the prediction of the rainfall event. But most of these factors are highly complex and require performing elaborate calculations to determine if the prediction is accurate or not. The factors that are taken into account can change the environment drastically. Several types of research have also employed a plethora of different parameters for prediction purposes, such as temperature, humidity, etc.

The addition of several factors increases the overall accuracy of the system by a large margin. This is highly useful and can be used extensively for optimized and accurate predictions. The introduction and implementation of more and more attributes also increase the computational complexity of the system by a considerable margin. This is counter-intuitive but as an increasing number of factors are being considered, the calculation and integration of all such factors is very time consuming and would also defeat the purpose.

Machine Learning plays an important part in this scenario. The Machine Learning algorithms have been highly useful and have resulted in inaccurate predictions. This is due to the fact that the Machine Learning Algorithm has the characteristics to utilize the past data to compute and analyze the various different attributes to predict the event in the future. Several prediction algorithms have been discussed by various authors and all of them have provided valuable insight into the process of Machine Learning. various authors have combined a large number of Rainfall Prediction algorithms that have utilized the inter-comparison of the methodologies to create a hybrid system capable of accurate predictions. Some of the authors have also combined various different attributes along with the PWV to increase the accuracy of the prediction even further. The Machine Learning algorithm determines the performance of a particular algorithm.

In this paper, section 2 is dedicated for literature review of past work and Finally Section 3 concludes this paper.

II. LITERATURE REVIEW

Yajnaseni Dash proposes and effective scheme for the prediction of rainfall in the summer monsoon season using ANN. The dataset that is utilized for this purpose is taken by the IITM. Ten rain gauge stations were utilized in a fixed network in a city in Kerala [1]. The presented system utilized two artificial intelligence approaches to find out the summer monsoon rainfall of Kerala. SLFN architecture utilizes a small number of neurons in the first layer. The LM algorithm is utilized in the proposed methodology. The second one is the Extreme learning Machine (ELM) technique is used to determine the output weights using the Moore-Penrose inverse and the hidden biases and input weights are randomly selected. The experimental results showed SLFN is not as powerful as the ELM technique using the RMSE and MAE scores.

A Kala [2] presented a system for rainfall prediction by using a Feed-Forward Neural Network (FFNN) algorithm. The process of predicting rainfall consist of a collection of the open-source weather data, preprocessing of the data, building the FFNN model with the training data, validating the FFNN model with the test data and evaluating the model by taking the difference between predicted output and desired output. The accuracy obtained by using the model was 93.55 %. The result showed that the FFNN model can be used as a predictive algorithm for rainfall prediction.

Mary N. Ahuna presents an innovative model for the prediction of a rainfall event ahead of its occurrence [3]. The selection of the digital modulation technique is useful for the determination of the quality of service and availability of the link. The data used in the proposed system was extracted from the disdrometer measurements. The dataset was segregated into a set of events such as thunderstorm events, showers and drizzle. A three-layer network was implemented withone neuron in the outer layer, five neurons in the hidden layer and three input neurons in the input layer.

Ida Wahyuni proposed Tsukamoto fuzzy inference systems (FIS). Tsukamoto FIS outline the connection among outputs and inputs of the framework making usage of a collection of if-then fuzzy regulations. The principle powers of fuzzy inference systems (FIS) are of their potential to conclude a critical issue completely from the data [3]. The data for forecasting criteria is rainfall data from 10, 20, 170 and 340 days before. Tsukamoto fuzzy inference framework approach of making a rule-based in the form of "causation" or "if-then". The first step in computing the Tsukamoto FIS technique is to define a fuzzy rule. The next step is to compute the degree of membership in line with the rules which have been made. Once the degree of membership value of every fuzzy rule is known, the value of the alpha forecast can be resolved by the usage of fuzzy set operations. The last step is to find the outcomes or the crisp values through

defuzzification process.The Center Average Defuzzyfier is the technique used in this process. Results of prediction are better when using the Tsukamoto fuzzy inference system and compared with the prediction results from the GSTAR method.

Chandrasegar Thirumalai represented a survey of the linear regression method for theforecasting of rainfall. The linear regression method utilizes the known value of a season which is used for predicting the unknown value of another season. If Kharif and rabi are two connected variables, then the linear regression technique enables us to forecast the value of rabbi for a given value of Kharif or vice versa. The linear regression technique can build the regression line that would represent the system and will help to find out the crop yield and its dependence on rainfall[5]. In fundamental straight relapse, scores on one variable are forecasted from the scores on a moment variable. The outcome using the linear regression approach which suggests that the data results predicted only depends on the preceding year's data.

Choujun Zhan proposed a technique to forecast rainfall which is relianton multiple sites nearby for weather information. The extensive climate data collected from a collection of close byweather sites are refined, and then utilized traditional deep learning algorithms (including long-short term memory (LSTM) networks), recurrent neural networks (RNN), and convolutional neural networks (CNN), and ensemble learning algorithms (including XGboost, GBDT,and Adaboost) to predict short term Precipitation. The precipitation level prediction is convenient than forecasting the precipitation value. Ensemble algorithm “Bag” can provide the highest accuracy., the convolutional neural network with only two layers performs well for predicting the precipitation value [6].

Cristian Rodriguez Rivero [7] presented a prediction system depend on energy-related to sequence that utilize incomplete data for regulating its attributes concurrent the historically recorded information is comparatively short. The parameter for filters among its smoothness is put in the function of the unevenness of the short time series. Hurst's parameter is utilized in the learning procedure to modify on-line the collection of patterns, the collection of filter's inputs and the collection of iterations. This H works for a thought of aliasing of a signal, and to establish its dependency. The learning rule presented to regulate the ANNs weights depends on the LM technique and energy-related to series as aninput. The result proved that the forecasting framework depends on energy-related to series has an ideal performance from numerous samples of MG equation. Besides, this prediction tool is proposed to be used by farmers to increase their profits, reducing profit losses over the inaccuracy of future movements to increase their utilities.

Mr. C.P Shabariram proposed a unique solution to spatial-temporal characteristics data management depends on the Map-reduce framework. The SVM or support vector machines for the processing and classification of the temporal characteristics using the MapReduce framework. The calculation outputs a set of key/value pairs by utilizing a collection of input key/value pairs. Map procedure takes caries of dividing the rainfall information spatial data [8]. The SVM is a data mining technique that is used to mine the information of meteorological data dependingupon the relationshipsin-betweenthe total number of support vectors involved and the fault-tolerance technique. This proposed system works as an application that allowslarge raw rainfall data to be easily categorized and analyzed.

Minghui Qiu presented a multitasking CNN (Conventional Neural Network) model that automatically derives characteristics from the time series measured at observation sites and/ utilizesmultitasking to leverage the connection between the multiple sites. The whole system has 3 main components: the first one is a feature transformation network (CNN model) to represent the multi-task module to incorporate site correlations, input features, and an output model to predict rainfall amount. Intensive experimentation proves that the presented technique performs significantly better than the traditional techniques[9].

A.K Daniel presented a fuzzy-based rainfall and maize prediction model. The rainfall prediction model utilizes NI Method which helps to predicta collection of natural disasters such as floods, cyclones, etc. The attributes that affect rainfall areprimarilyhumidity and temperature. The proposed methodologycontains two-parameter humidity and temperature [10]. The dataset of the presentedsystem for forecast of Area containing Maize Production is supported by the NI method. The performance of the presented techniquedisplays a significant improvement in maize production as quantity and quality.

Shilpa Manandhar [11] presented a short-term rainfall prediction by utilizing GPS-based PWV in the tropical climate. An algorithm is proposed to forecast the immediately expected rain occasion in the next 5 min give the PWV data of 30 min. The proposed algorithm acquires two threshold variables; season-based PWV values and double imitative of PWV values. Remarkable diurnal and seasonal variety of PWV are found over nearly all of the IGS stations. The PWV values in tropical regions are usually higher and have a small range of difference. The proposedmethodologydefines the seasonal parameters of PWV values to predict rainfall in a tropical climate. The database is collected from Singapore, NTUS GPS station. The results showed that the proposed algorithm works well. The presentedmethodology is validated using the data from two more tropical stations SALU and SNUS. The presentedtechnique shows good accuracy for new stations as well.

Xiaoli Li introduced a deep belief convolutional network for forecasting the rainfall. The presentedtechnique can predict therainfall from the deep stimulation the essential hydrological factors based on the complex and multi-layer architecture [12]. The proposed system includes four-module testing, optimizing CDBNs,training CDBNs, and data preprocessing. The first module is used for the preprocessing of data. It is used for the purpose of normalizing the data. The second module, is utilized for the training and configuration of the initial weights of CDBNs by using the training data. Then, global supervised learning is employed for fine-tuning CDBNs parameters. The third module is then utilized for the optimization of the CDBNs for achieving more accurate simulation results. The fourth module is testing. In this module, a testing set is used to testifying the performance of the constructed rainfall-runoff model. The runoff values are forecasted by the model and the runoff output is normalized according to the original scale. The experiments indicate that the proposed approach could accurately predict the rainfall-runoff. So, the given algorithm has adjustable predictability, under one model and the same historical data is implemented in multiple different manners. The rainfall-runoff forecasttechnique can be improved to a similar climate zone. For different climatic conditions, it needs to be corrected for predicting the runoff in the new zone.

Jun-He Yang [13] presented a novel forecasting model forrainfall improves the prediction performance by integrating the nonlinear and core functions for selection. The presented model utilized a non-linear feature for integrating feature selection technique with the help of SVR to improve the forecast performance. The experimental indicates that the proposedmethodology has a superior performance than the conventional models. And the result shows that after attributes selection, the proposed model is also more superior to the traditional models that utilize the time-series for the purpose of forecast.

Joko Azhari Suyatno presented an innovative schemefor rainfall prediction in Bandung regency. The authors utilized the datasets containing 7 attributes is created from Bandung regency BMKG's by utilizing a classification technique using C4.5 algorithm. The results of the experiments indicate that the proposed methodology reaches a highest testing accuracy is 93%.Pruning of the decision tree outputs the results from the scenario. The proposed methodology has been crucial in ameliorating the harvesting results and helping the people of the area effectively [14].

Shilpa Manandhar [15] presented a thorough study of distinct weather parameters. Along with the distinct weather attributes, the seasonal and diurnal parameters are also observed, which are commonly neglected in many studies. These weather attributes and seasonal factors are personally evaluated for rainfall prediction. Those attributes that are vital for rainfall prediction are identified, and a machine learning algorithm is applied, which shows significant enhancement in rainfall prediction precision as a contrast to the existing technique. For the purpose of rainfall prediction, the samples are labeled as either norainfall or rainfall. Then the SVM (Support Vector Machine) is used to categorize no rainfall and rainfall cases using distinct weather attributes as features. All the characteristics play an important role in rainfall classification, while features like HoD, DoY, Sr and PWV in specific indicate the potential for the prediction.

The above researches have been elaborated in the comparative study table given below.

Table 1: Comparative Study of all above methods

No.	Title	Author	Publication & Year	Parameter/ Attributes	Technique/ Algorithm Used	Strength	Weakness
1	Rainfall Prediction of A Maritime State	Yajnasen i Dash, S.K. Mishra and B.K.	2017 International Conference on Intelligent	Single-layer Feed-Forward Neural Network	Levenberg-Marquardt (LM) algorithm	The experimental results showed that ELM outperforms SLFN based on MAE (%) and	The input weights and hidden biases are selected randomly.

	(Kerala), India Using SLFN And ELM Techniques	Panigrahi	Computing, Instrumentation and Control Technologies (ICICICT), 23 April 2018.	(SLFN)		RMSE (%) scores.	
2	Prediction of Rainfall Using Artificial Neural Network	A. Kala; S. Ganesh Vaidyanathan	2018 International Conference on Inventive Research in Computing Applications (ICIRCA), 03 January 2019.	open-source weather data and preprocessing of the data	Feed-Forward Neural Network (FFNN) algorithm	The result indicated that the FFNN model can be used as a predictive algorithm for rainfall prediction.	The accuracy obtained by using the model was 93.55 %.
3	Rainfall Rate Prediction Based on Artificial Neural Networks for Rain Fade Mitigation Over Earth-Satellite Link	Mary N. Ahuna, Thomas J. Afullo and Akintunde A. Alonge	2017 IEEE Africon, 07 November 2017.	Disturbances resulting from the forecasted rainfall rate and an appropriate digital modulation technique	Joss-Waldvögel (JW) RD-80 disdrometer measurements	A three-layer network was implemented with one neuron in the outer layer, five neurons in the hidden layer and three input neurons in the input layer.	Increased Computational Complexity.
4	Rainfall prediction in Tengger region Indonesia using Tsukamoto fuzzy inference system	Ida Wahyuni, Wayan Firdaus Mahmudy and Atiek Iriany	2016 1st International Conference on Information Technology, Information Systems and Electrical Engineering (ICITISEE), 02 January 2017.	fuzzy rules, fuzzy set operations and fuzzy if-then regulations	Tsukamoto fuzzy inference systems (FIS)	Results of prediction using the presented technique are better when compared with the forecasting results with the GSTAR method.	Increased Time complexity.
5	Heuristic Prediction of Rainfall Using Machine Learning Techniques	Chandrasegar Thirumalai, K Sri Harsha, M Lakshmi Deepak, and K Chaitany	2017 International Conference on Trends in Electronics and Informatics (ICEI), 22 February 2018.	fundamental straight relapse, scores on one variable are foreseeing from the scores on a	linear regression	The outcome using the linear regression approach which suggests that the data results forecasted only depends on the preceding year's data.	Dependency on previous years data has not been demonstrated properly.

		a Krishna		moment variable			
6	Daily Rainfall Data Construction and Application to Weather Prediction	Choujun Zhan, Fujian Wu, Zhengdong Wu, and Chi K. Tse	2019 IEEE International Symposium on Circuits and Systems (ISCAS), 01 May 2019.	precipitation level prediction	CNN, RNN, LSTM, Adaboost, XGBoost	The precipitation level prediction is convenient than forecasting the precipitation value. Ensemble algorithm "Bag" can provide the highest accuracy.	For predicting the precipitation value, the convolutional neural network with only two layers performs well
7	Short-Term Rainfall Time Series Prediction with Incomplete Data	Cristian Rodriguez Rivero, Hector Daniel Patiño and Julian Antonio Pucheta	2015 International Joint Conference on Neural Networks (IJCNN), 01 October 2015.	MG equations	ANN	The result proved that the forecasting framework depends on energy-related to series has an ideal performance from numerous samples of MG equation.	Increased Computational Complexity.
8	Rainfall analysis and rainstorm prediction using MapReduce Framework	C.P Shabariram, K.E. Kannammal and T. Manojpraphakar	2016 International Conference on Computer Communication and Informatics (ICCCI), 30 May 2016.	Spatio-temporal characteristics data management	Support Vector Machine (SVM)	This complete system works as an application that allowslarge raw rainfall data to be easily categorized and analysed.	To extract the information of climate data depends on the relationship between the proposed technique and the total number of support vectors involved.
9	A Short-Term Rainfall Prediction Model Using Multi-Task Convolutional Neural Networks	Minghui Qiu, Peilin Zhao, Ke Zhang, Jun Huang, Xing Shi, Xiaoguang Wang, and Wei Chu	2017 IEEE International Conference on Data Mining (ICDM), 18 December 2017.	feature transformation network,	CNN	Automatically mine characteristics from the measured time series data from observation sites and utilize the connection between the multiple sites for weather forecasting via multitasking.	Extensive experimentation proved that the presented technique executes significantly better than the baseline technique
10	Fuzzy Based Prediction Model Using Rainfall Parameter for North eat India Maize	A.K Daniel, Prachi Sharma, and Rashi Srivastava	2018 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and	The presentedtechnique consists of two-parameter temperature and humidity	Newton interpolation method	The performance of the proposed methodologyindicates a significant improvement in maize production as quantity and quality.	Only two parameters utilized.

	production		Computer Engineering (UPCON), 03 January 2019.				
11	GPS-Derived PWV for Rainfall Nowcasting in Tropical Region	Shilpa Manandhar, Yee Hui Lee, Yu Song Meng, Feng Yuan, and Jin Teong Ong	IEEE Transactions on Geoscience and Remote Sensing, Volume: 56, Issue: 8, Aug. 2018, 15 June 2018.	season-based PWV values and double imitative of PWV values	IGSstations	The authors presented a short-term rainfall forecastingthrough the utilization of GPS-based PWV in the tropical climate	The proposed algorithm is confirmed utilizing the data from only two more tropical stations SALU and SNUS
12	A Method of Rainfall-Runoff Forecasting Based on Deep Convolution Neural Networks	Xiaoli Li, Zhenlong Du and Guomei Song	2018 Sixth International Conference on Advanced Cloud and Big Data (CBD), 12 November 2018.	essential climate factors reliant on the complicated and multi-layer architecture	CDBN	The authors introduced a deep belief convolutional network for forecasting the rainfall-runoff	The amount of available data for the purpose of prediction is very less.
13	A Novel Rainfall Forecast Model Based On Integrated Non-Linear Attributes Selection Method And Support Vector Regression	Jun-He Yang, and Ching-Hsue Cheng	2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), 14 January 2016.	non-linear features selection, time series forecast	SVR and RMSE	The authors presented a unique rainfall prediction model that used the non-linear features integrated for the selection technique to find the core features and enhance forecast performance.	The presented technique is also superior to the other models in time-series prediction only.
14	Rainfall Forecasting in Bandung Regency Using C4.5 Algorithm	Joko Azhari Suyatno, Fhira Nhita and Aniq Atiqi Rohmawati	2018 6th International Conference on Information and Communication Technology (ICoICT), 12 November 2018.	Dataset on this research is a weather dataset taken from BMKG with 7 attributes from 2005 to 2016	C4.5 algorithm	The execution of the C4.5 algorithm as expected can improve the people of Bandung regency in relation to their activities in the agriculture sector.	The experimental outcome of the highestaccuracy is quite low.
15	A Data-	Shilpa	IEEE	Weather	SVM (Support	The researchers	Features like HoD,

	Driven Approach for Accurate Rainfall Prediction	Manandhar, Soumyabrata Dev, Yee Hui Lee, Yu Song Meng and Stefan Winkler	Transactions on Geoscience and Remote Sensing, Volume: 57, Issue: 11, Nov. 2019, 06 August 2019.	attributes, seasonal factors and diurnal parameters.	Vector Machine)	presented a thorough study of distinct weather parameters and seasonal factors that affect the rainfall prediction.	DoY, SR, , PWV, and in specificindicate potential for rainfall forecasting better than the proposed technique.

III. CONCLUSION

The methodology discussed in this paper for the purpose of rainfall prediction has been evaluated. A large number of papers and researches performed on the topic of rainfall prediction are elaborated in detail in this publication. The various different techniques and approaches have been studied in detail to understand the implementation of an accurate and efficient rainfall prediction technique.The previous works that have been analyzed that have been used to shape our technique that utilizes the Hidden Markov Model and Fuzzy classification to achieve a high level of accuracy in the system. the proposed methodology also utilizes K Means Clustering and Linear regression which will be elaborated in detail in the future research.

REFERENCES

[1] Yajnaseni Dash, S.K. Mishra and B.K. Panigrahi, "Rainfall Prediction Of A Maritime State (Kerala), India Using SLFN And ELM Techniques", 2017 International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT), 23 April 2018.

[2] A. Kala; S.Ganesh Vaidyanathan, "Prediction of Rainfall Using Artificial Neural Network", 2018 International Conference on Inventive Research in Computing Applications (ICIRCA), 03 January 2019.

[3] Mary N. Ahuna, Thomas J. Afullo and Akintunde A. Alonge, "Rainfall Rate Prediction Based On Artificial Neural Networks For Rain Fade Mitigation Over Earth-Satellite Link", 2017 IEEE Africon, 07 November 2017.

[4] Ida Wahyuni, Wayan Firdaus Mahmudy and Atiek Iriany, "Rainfall prediction in Tengger region Indonesia using Tsukamoto fuzzy inference system", 2016 1st International Conference on Information Technology, Information Systems and Electrical Engineering (ICITISEE), 02 January 2017.

[5] Chandrasegar Thirumalai, K Sri Harsha, M Lakshmi Deepak, and K Chaitanya Krishna, "Heuristic Prediction of Rainfall Using Machine Learning Techniques", 2017 International Conference on Trends in Electronics and Informatics (ICEI), 22 February 2018.

[6] Choujun Zhan, Fujian Wu, Zhengdong Wu, and Chi K. Tse, "Daily Rainfall Data Construction and Application to Weather Prediction ", 2019 IEEE International Symposium on Circuits and Systems (ISCAS), 01 May 2019.

[7] Cristian Rodriguez Rivero, Hector Daniel Patiño and Julian Antonio Pucheta, "Short-Term Rainfall Time Series Prediction With Incomplete Data", 2015 International Joint Conference on Neural Networks (IJCNN), 01 October 2015.

[8] C.P Shabariram, K.E. Kannammal and T. Manojpraphakar, "Rainfall analysis and rainstorm prediction using MapReduce Framework", 2016 International Conference on Computer Communication and Informatics (ICCCI), 30 May 2016.

[9] Minghui Qiu, Peilin Zhao, Ke Zhang, Jun Huang, Xing Shi, Xiaoguang Wang, and Wei Chu, "A Short-Term Rainfall Prediction Model Using Multi-task Convolutional Neural Networks", 2017 IEEE International Conference on Data Mining (ICDM), 18 December 2017.

[10] A.K Daniel, Prachi Sharma, and Rashi Srivastava, "Fuzzy Based Prediction Model Using Rainfall Parameter for North eat India Maize production", 2018 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), 03 January 2019.

[11] Shilpa Manandhar, Yee Hui Lee, Yu Song Meng, Feng Yuan, and Jin Teong Ong, "GPS-Derived PWV for Rainfall Nowcasting in Tropical Region", IEEE Transactions on Geoscience and Remote Sensing, Volume: 56, Issue: 8, Aug. 2018, 15 June 2018.

[12] Xiaoli Li, Zhenlong Du and Guomei Song, "A Method of Rainfall-Runoff Forecasting Based on Deep Convolution Neural Networks", 2018 Sixth International Conference on Advanced Cloud and Big Data (CBD), 12 November 2018.

[13] Jun-He Yang, and Ching-Hsue Cheng, "A Novel Rainfall Forecast Model Based On Integrated Non-Linear Attributes Selection Method And Support Vector Regression", 2015

12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), 14 January 2016.

[14] Joko Azhari Suyatno, Fhira Nhita and Aniq Atiqi Rohmawati, "Rainfall Forecasting in Bandung Regency Using C4.5 Algorithm", 2018 6th International Conference on Information and Communication Technology (ICoICT), 12 November 2018.

[15] Shilpa Manandhar, Soumyabrata Dev, Yee Hui Lee, Yu Song Meng and Stefan Winkler, "A Data-Driven Approach for Accurate Rainfall Prediction", IEEE Transactions on Geoscience and Remote Sensing, Volume: 57, Issue: 11, Nov. 2019, 06 August 2019.

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