Analyze IoT Sensor Data
Using
Machine Learning

Submitted by

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Contents

1. Introduction

1.1 Overview

The Internet of Things (IoT) refers to a system of interrelated, internet-connected objects that are able to collect and transfer data over a wireless network without human intervention. The objects are nothing but the sensors, gateways etc. A lot of sensor types are used in the IoT system depending on the application. Some of them are temperature sensor, proximity sensor, humidity sensor, pressure sensor, chemical sensor, gas sensor, infrared sensor, image sensor etc.

Sensor data is the output of a device sensor that detects and responds to some type of input from the physical environment. The output may be used to provide information or input to another system or to guide a process.

IoT devices sometimes run on their own embedded software or firmware, but they can also use the Cloud to process data. The data that is sent is stored and processed within the cloud server, i.e in a data center using data analysis. As soon as the data reaches the Cloud, the software processes the data.

Machine learning is a method of data analysis that automates analytical model building. It is a branch of artificial intelligence based on the concept that systems can learn from data, identify patterns and make decisions with minimal human intervention. The cloud software uses machine learning technique to analyze the data received from IoT sensors. In this project, rainfall data is analyzed using machine learning technique in cloud and rainfall prediction is done.

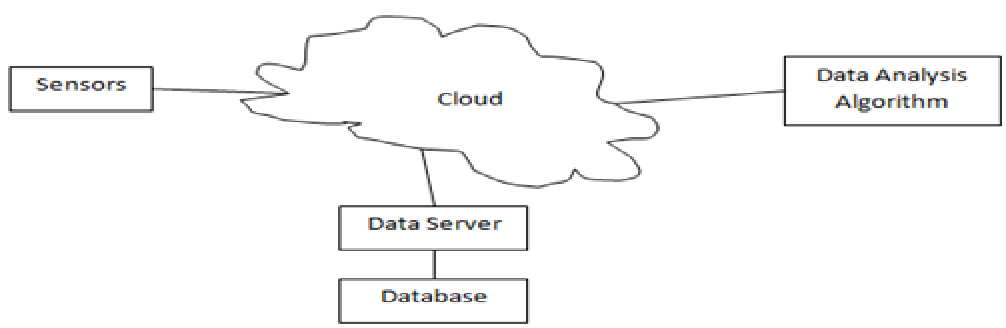

Fig. 1: IoT Data Processing

1.2 Purpose

Rainfall prediction is the application of science and technology to predict the state of the atmosphere. It is a climatic factor that affects many human activities like agricultural production, construction, power generation, forestry and tourism, among others. Therefore, it is very much important to predict the rainfall over a region in order to take timely action. For example, consider the field of agriculture .In most of the region, where rain water is the only source of irrigation, farmers start their farming in monsoon season. Due to the pollution factor, it is quite difficult in the part of farmer to take decision on when to start farming. This is because monsoon depends on so many factors and it may be delayed in some region due to climatic factor. In this case, the problem of farmer can be resolved if he is provided with accurate rainfall prediction information.

The weather is dynamic in nature.Therefore, stastical techniques are not able to provide accurate data relating to rainfall forecasting.The purpose of this project is to collect environmental data relating to rainfall using sensors in IoT environment , storing it in cloud and processing it using machine learning technique.

2. Literature Survey

2.1 Existing Problem

A lot of researchers are working since a long time for accurate prediction of the rainfall-whether it will rain or not depending on the environmental parameter values collected. But till now, no such method has developed for this purpose. Sometimes, it is seen that the forecasted information on rainfall for a geographical area turns false. In this case, the people are affected much. This may be due to improper analysis of data using existing technique. Another factor is that the continuous change in environment due to pollution and hence change in parameters that are responsible for accurate rainfall prediction. In this case, the existing techniques are may be to draw a conclusion on rainfall from the collected information.

Some of the studies done by researchers is described in Table 1.

Table 1: Literature Review

Sl	Author Details	Journal Details	Technique Used	Task Done	Limitation
1	Tomoki Kashiwao, Kochi Nakayama, Shin Ando,Kenji lkeda, Monyong Lee, Alireza Bahadori	A neural network-based local rainfall prediction system using meteorological data on the Internet: A case study using data from the Japan Meteorological Agency,Elsevier:Applied soft computing, volume 56, July 2017, Pages 317-330	Neural Network	Analysis of precipitation status and volume of precipitation	No proper technique to collect proper environmental data and it does not consider the factors likealtitude, ocean current, airflow at the time of data collection
2	Eslam Hussein. Mehrdad Ghaziasgar, Christopher Thron	Regional Rainfall Prediction Using Support Vector Machine Classification of Large-Scale Precipitation Maps,arxiv:2007.15404v1[cs. LG] 30 July 2020	Support Vector Machine	Precipitation prediction from precipitation map	Less no. of features used for rainfall prediction.
3	G. Bala Sai Tarun, J.V. Sriram, K. Sairam, K. Teja Sreenivas, M.V.B.T. Santhi	Rainfall prediction using Machine Learning Techniques , International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8 Issue-7, May, 2019	Support vector machines, Artificial Neural Networks, Logistic regression.	Qualitative Analysis of rainfall prediction	Least no. of parameters are used and geographical location of the area is not taken into consideration.

4	Xiaobo Zhang , Sachi Nandan Mohanty, Ajaya Kumar Parida , Subhendu Kumar Pani, Bin Dong, , Xiaochun Cheng	Annual and Non-Monsoon Rainfall Prediction Modelling Using SVR-MLP: An Empirical Study From Odisha, IEEE Access,Volume 8, 2020	Support Vector , Regression and Multilayer perception	Analysis of maximum rainfall in annual and non-monsoon session	Least no. of parameters are used
5	Nazim Osman Bushara, Ajith Abraham	Weather Forecasting in Sudan Using Machine Learning Schemes, Journal of Network and Innovative Computing ISSN 2160-2174 Volume 2 (2014) pp. 309-317	Linear Regression, Multilayer Perceptron, k-nearest-neighbour classifier, KStar, Additive Regression	Examined relationship of rainfall with parameters like Wind Direction, Humidity, Temperature, and Wind Speed	Least no. of parameters are used
6	B.Narayanan, Dr.M.Govindarajan	Rainfall Prediction based on Ensemble Model, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 5, May 2016	AdaSVM and AdaNaive	Analysis of accuracy and classification error	No. of input data is less.

2.2 Proposed Solution

The architecture of the IoT data analysis model is given below:-

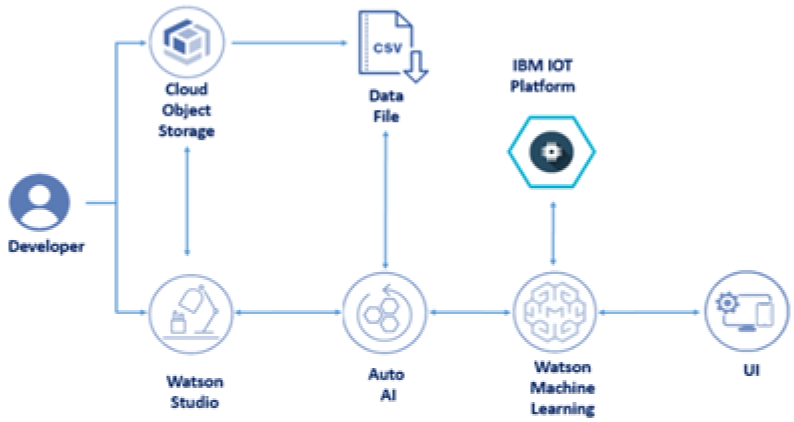

Fig. 2 : Architecture Of Data Analysis Model Using Machine Learning

The developer creates device for event generation for flow simulation. The devices accept data and send it to cloud where the data is stored in IBM cloud internal storage as .csv file. Then automatically, more than one machine learning algorithms are selected and models are created for analysis of stored data in Watson Studio environment. Auto AI service works with concurrently with Watson studio and it's job is to select the best algorithm among all selected algorithms. Watson machine learning service is used to do analyse stored data and the result of analysis is provided to the end user through the user interface.

In this project, Random Access Classifier algorithm is used for rainfall prediction. The details of the algorithm is described below:

Random Forest Classifier:- Random forest is a supervised learning algorithm which is used for both classification as well as regression. Random forest algorithm creates decision trees on data samples and then gets the prediction from each of them and finally selects the best solution by means of voting. It is an ensemble method which is better than a single decision tree because it reduces the over-fitting by averaging the result.The pseudo-code of the algorithm is given below:-

1. Start with the selection of random samples from a given dataset.

2. Next, this algorithm will construct a decision tree for every sample. Then it will get the prediction result from every decision tree.

3. In this step, voting will be performed for every predicted result.

4 . At last, select the most voted prediction result as the final prediction result.

Dataset is divided into two parts:-Training set and Testing set. Training set is used to make the model learn and testing set is used for testing the model behavior once the training is over.

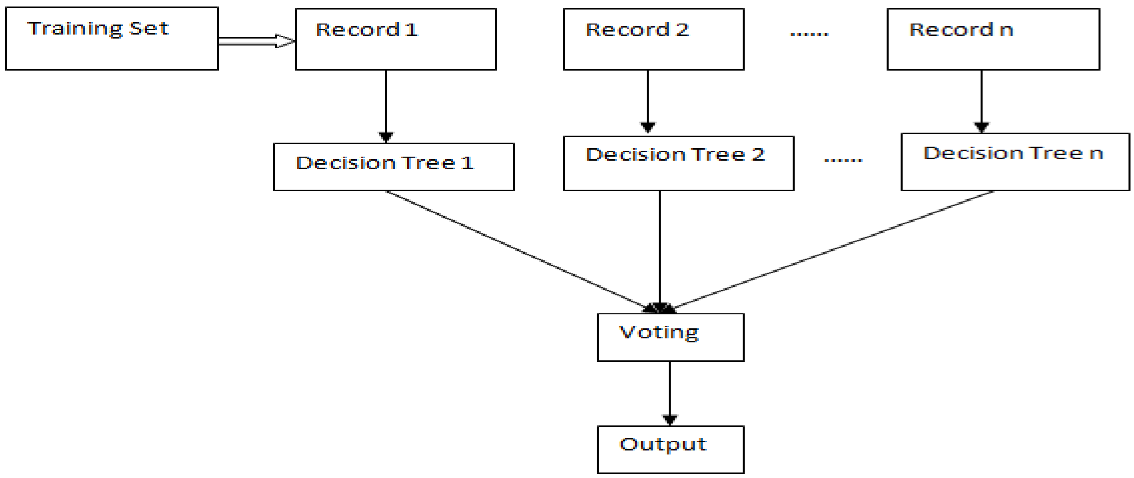

Fig.3 : Workflow of Random Forest Classifier

3. Theoritical Analysis

The question is whether it will rain next day or not. This is a complicated question because answer depends on a lot of environmental factors and the environment is dynamic in nature. It is not possible to gather all the required data over a continuous period and process them due to cost factor. In this case, attempt is made to reach at a suitable near optimal decision with available resources.

Random forests are a type of ensemble method which makes predictions by averaging over the predictions of several independent base models.It is a popular method for classification and regression. Random forests are built by combining the predictions of several trees, each of which is trained in isolation. Predictions of the trees are combined through averaging in case of regression and voting in case of classification. Random forest classifier is a faster technique that can handle non-linear data easily.

Our dataset contains one target variable named rainfall which is a binary variable. If there is the possibility of rain, the value is 1, otherwise 0. There are three input parameters : temperature, humidity and wind velocity. A binary classifier is sufficient to predict the information. Rainfall prediction requires continuous data and hence regression analysis of rainfall data is required. For this purpose, random forest classifier is used. The dataset contains a total of 1099 no. of records. It is divided into two sets: training set and testing set.

Training set contains 85% of records of the dataset and testing set contains remaining 15% records. The model is trained with the records belonging to traininig set using supervised learning technique and then deployed in cloud.Deployed model is used for rainfall analysis.

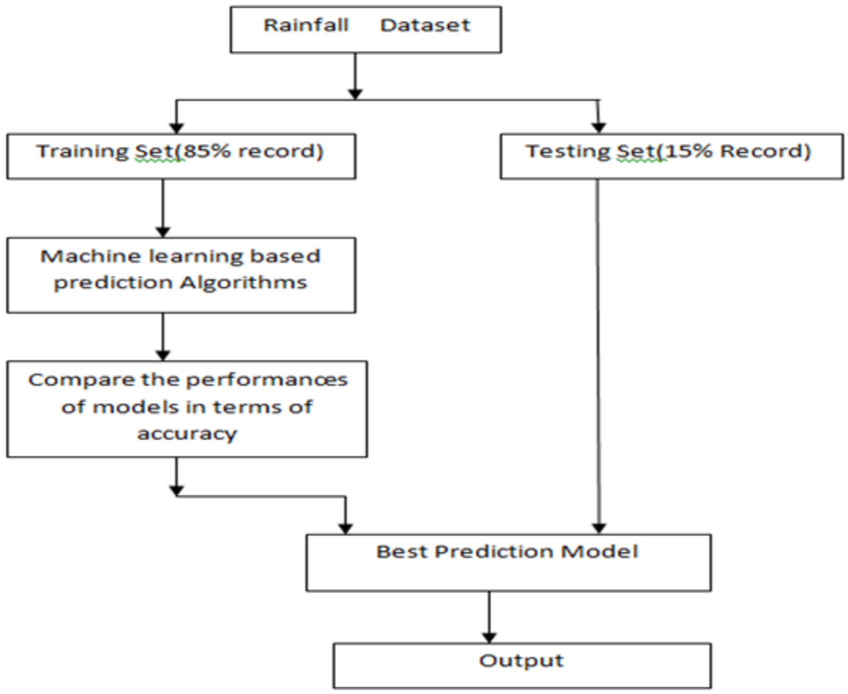

Fig. 4: Flowchart of Data Analysis using Machine Learning Technique

Forest is collection of trees and it is with no tree initially. Each time, a record from the dataset is selected at random and fit into tree. At each node, select m variables out of total M variables. Find the best split on the selected m variables. Grow the trees big until all the records of the set are exhausted.

4. Experimental Investigations and Result

In this work following services of IBM Cloud are used:

a. **Internet of Things Platform service:-**

This service is used for sensor data generation. Three types of sensors data are generated. These are temperature, humidity and wind velocity. A device for data simulation is created in Internet of Things Platform in IBM cloud. All these parameter values are simulated by uploading the rainfall data file containing these three parameters. More than one devices can be created if the no. of events is more than one. Data from the devices are passed to the parser whose task is to make the data ready for analysis by the analytics.This is because the raw data cannot be directly used by the analytics as it may result incorrect output.The device continuously simulates the data which is analyzed for rainfall forecasting.

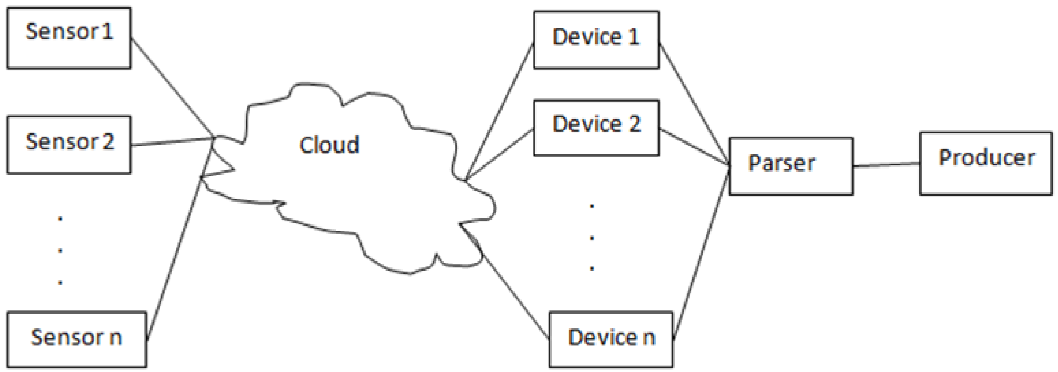

Fig. 5: Block Diagram of Streaming of Sensor Data

To stream sensor data, following steps need to be followed:

- Create an instance of service in Watson Internet of Things Platform.
- Create device to simulate sensor data
- Register the device with a device id and authentication token
- Use the device for simulation of sensor data.
- Stream sensor data to IoT platform using internal simulator.

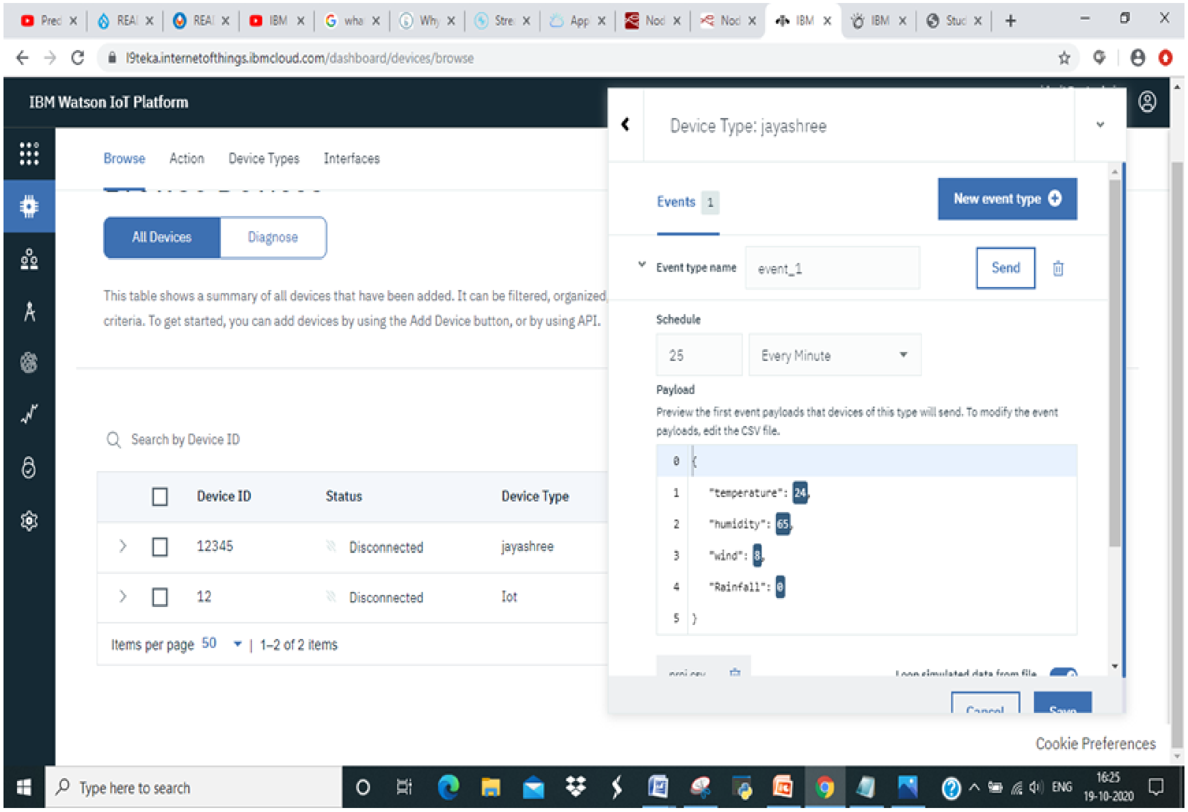

Fig. 6: Device creation for simulation with sample payload in json format in IBM Internet of Things Platform

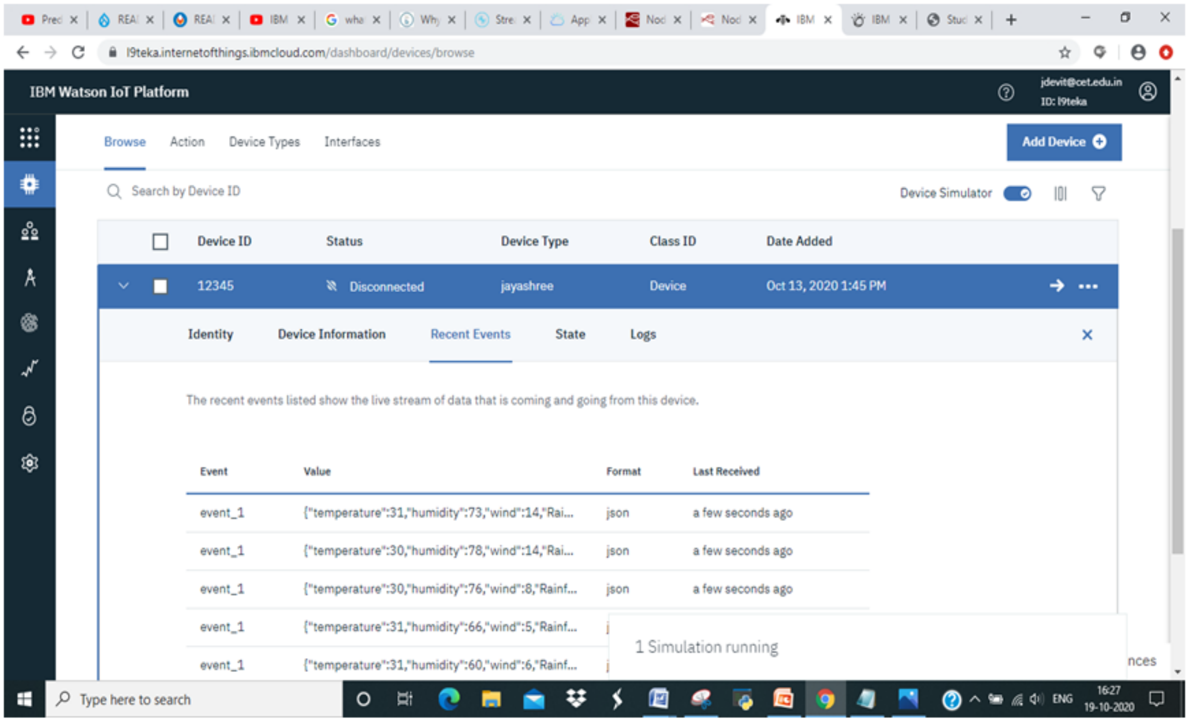

Fig. 7: Streaming of Sensor Data in IBM Internet of Things Platform

b. **<u>IBM Watson Studio:-</u>**

This service is used for analysis of simulated data in order to predict whether it will rain very next day or not. In this service, a pipeline of algorithms is selected for creation of prediction models and processing of simulated data automatically.

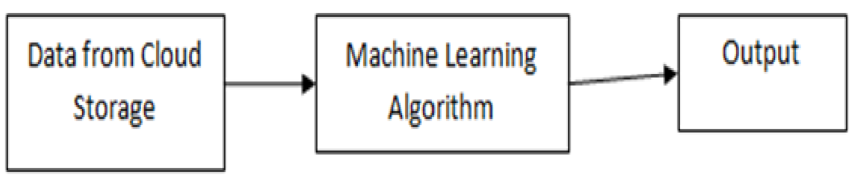

Fig. 8: Block Diagram of IoT Data Analysis Using Machine Learning Technique

Of course, this service also gives the flexibility to the user to select the algorithms. For rainfall dataset, it selected four variations of ‘Random Forest classifier’ for binary classification with different enhancements. Random forest classifier uses supervised learning technique to learn the data pattern at the time of training. The dataset used for training contains three input parameters: temperature, humidity and wind velocity. Similarly, the output parameter is rainfall. Supervised learning technique uses the target output parameter as the teacher at the time of training.The role of the teacher is to guide during the training process. Then the service starts to train the model with the available input and output data. Then the performances of the models are compared in terms of accuracy metric and the model with highest accuracy and lowest execution time is selected as the best model and gets deployed. Other parameters that are calculated at the time of performance calculation are confusion matrix, ROC curve, recall, F1 measure, log loss, average precision. Then the deployed model is used for rainfall prediction. Three IBM services work in unison from model building to predicting output:-IBM Watson Studio, IBM Machine Learning, IBM AutoAI experiment.

The model can be tested using the following metrics:

- *Confusion Matrix:*-A confusion matrix is a table that is often used to describe the performance of a classification model (or "classifier") on a set of test data for which the true values are known.
- *Accuracy and Precision*:-Accuracy is the total no. of correct predictions whereas precision is the ratio of correctly predicted positive observations to the total no. of observations.

  Precision = True Positive /(True Positive+False Positive)

- *Receiver Operating Characteristic curve(ROC) curve*:- It is a plot of the true positive rate against the false positive rate for the different possible cutpoints of a diagnostic test.

- *Recall*:-It is the ratio of correctly predicted positive observations to the all observations in actual class - yes.

  Recall = True Positive/(True Positive+False Negative)

- *F1 score:* - F1 Score is the weighted average of Precision and Recall.

  F1 Score = 2*(Recall * Precision) / (Recall + Precision)

- *Log loss*:- Log Loss quantifies the accuracy of a classifier by penalising false classifications

To build machine learning model, following steps are followed:

- Create an instance of IBM Watson Studio service

- Create space for a project
- Add simulated data
- Add and associate AutoAI Experiment for data analysis
- Configure AutoAI Experiment
- Run the experiment

✓ Split the simulated data into 2 parts:-one for training and another for testing

✓ Select target parameter

✓ Select the performance metric

✓ Create pipeline

✓ Run experiment

For this project, 4 pipelines are created automatically using Random Forest Classifier algorithm using different enhancement and trained with the reccords from training set.Then the performance of these pipelines are measured using some performance metric and then the pipeline 1 is selected as best pipeline and deployed in cloud for prediction purpose.

The performance comparison of different pipelines are given below:-

Pipeline leaderboard

Rank ↑	Name	Algorithm	Accuracy (Optimized)	Enhancements	Build time
★ 1	Pipeline 1	Random Forest Classifier	0.938	*None*	00:00:01
2	Pipeline 2	Random Forest Classifier	0.938	HPO-1	00:00:12
3	Pipeline 3	Random Forest Classifier	0.931	HPO-1 FE	00:00:46
4	Pipeline 4	Random Forest Classifier	0.931	HPO-1 FE HPO-2	00:00:39

Fig. 9: Pipeline leaderboard showing the best pipeline

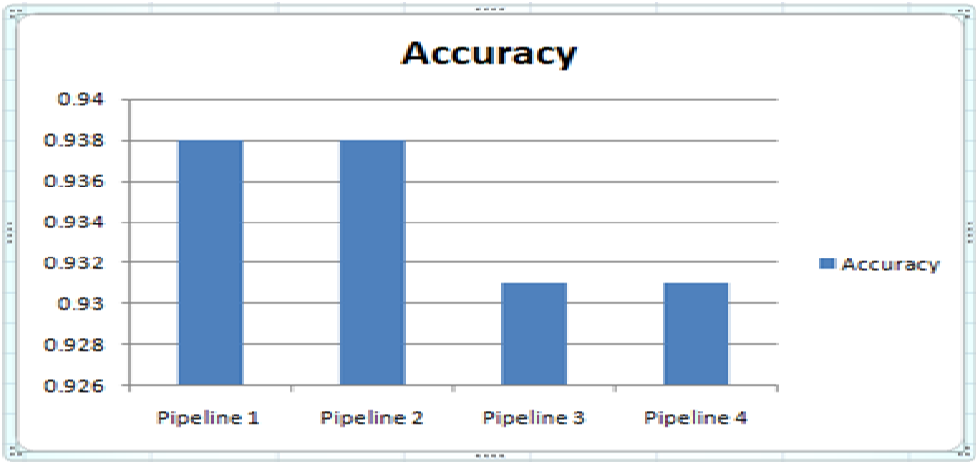

Fig. 10: Accuracy of different pipelines

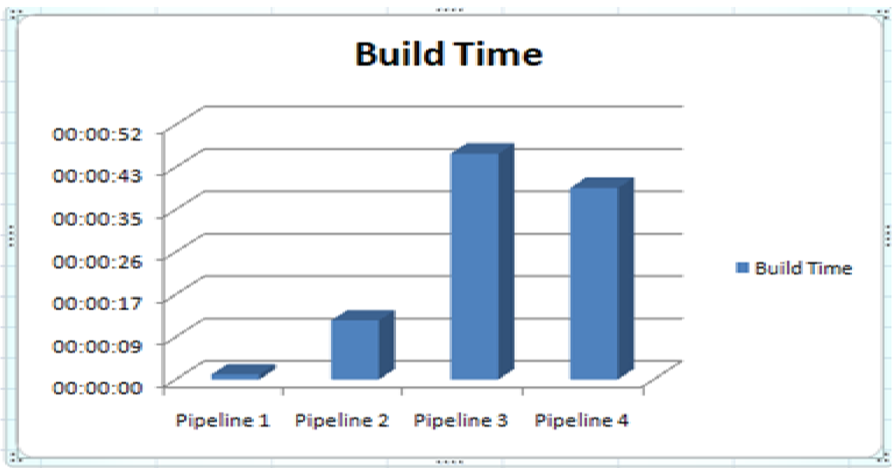

Fig. 11: Build time of different pipelines

Table 2: Data extracted from Confusion Matrix of Different Pipeline

	No. Of Instances Correctly Predicted	**No. Of Instances Incorrectly Predicted**
Pipeline 1	152	13
Pipeline 2	152	13
Pipeline 3	153	12

Pipeline 4	153	12

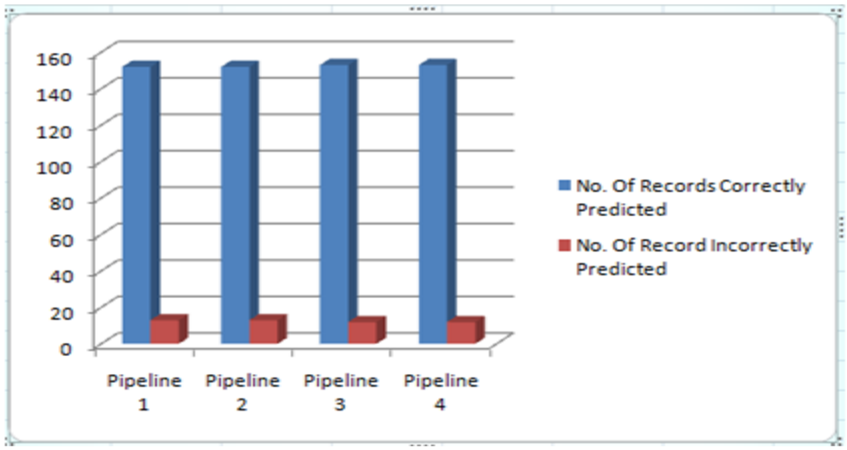

Fig. 12: Graphical Representation of Table 2.

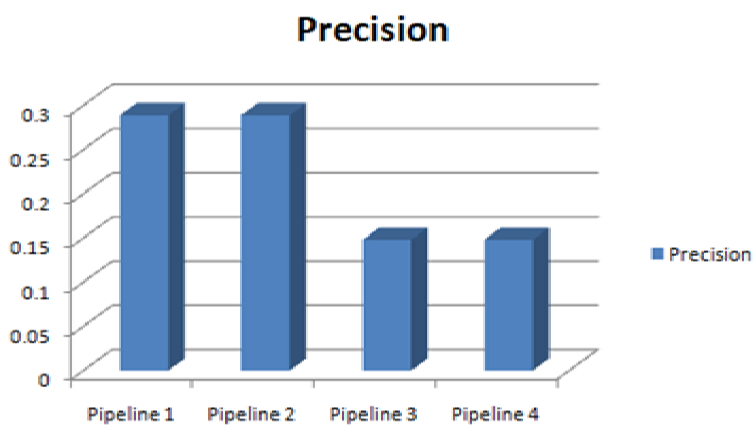

Fig. 13: Accuracy of Different Pipelines

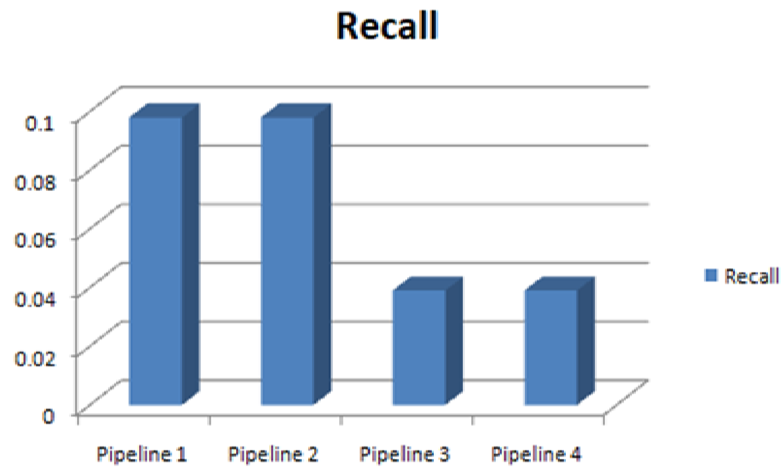

Fig. 14: Recall of Different Pipelines

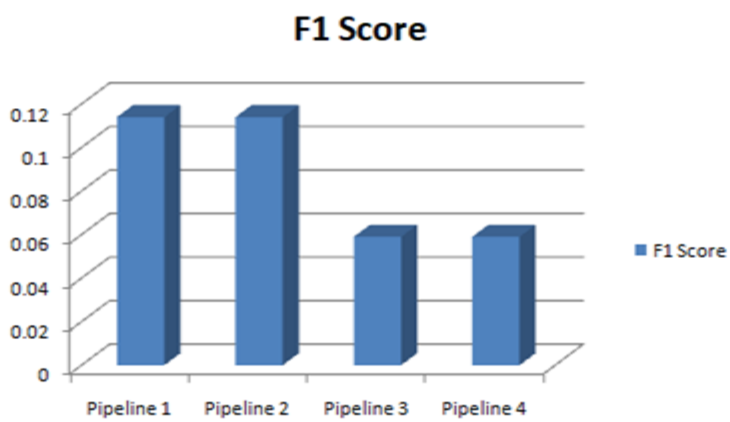

Fig. 15: F1 Score of Different Pipelines

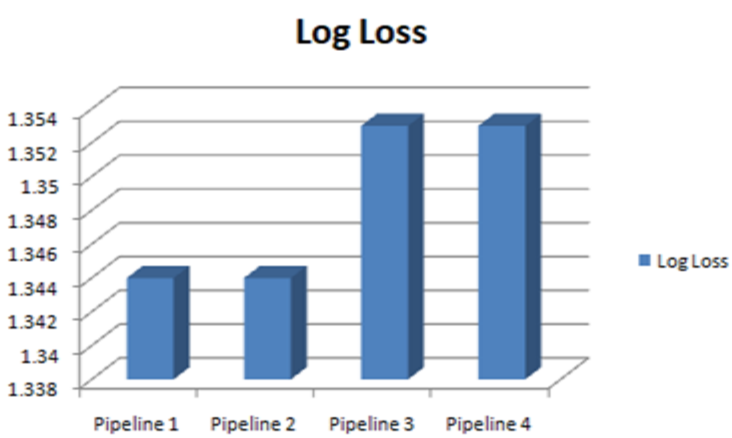

Fig. 16: Log Loss of Different Pipelines

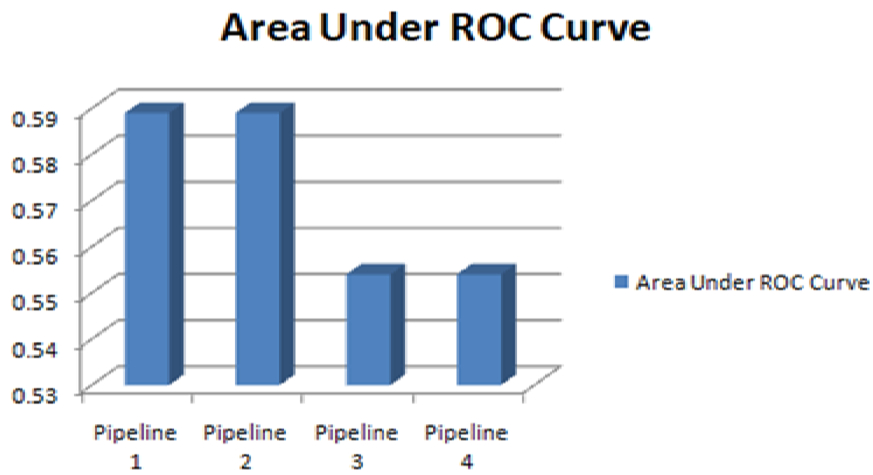

Fig. 17: Area Under ROC Curve for Different Pipelines

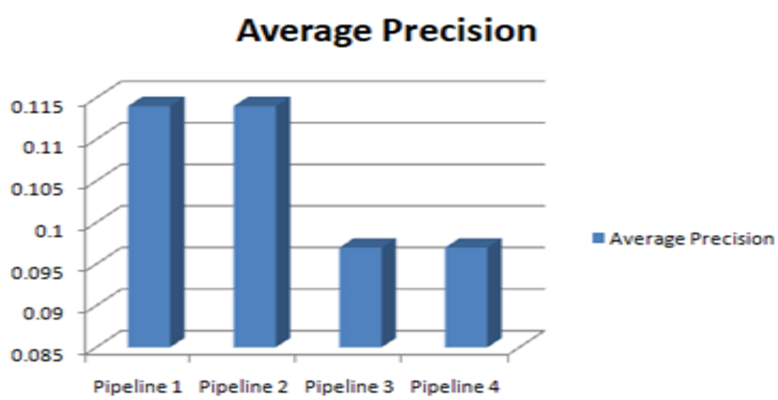

Fig. 18: Average Precision of Different Pipelines

Table 3: Different Performance Metric Values of Pipelines

Pipeline No.	Accuracy	Area Under ROC Curve	Precision	Recall	F1 Measure	Average Precision	Log Loss
1	0.938	0.589	0.289	0.098	0.146	0.114	1.344
2	0.938	0.589	0.289	0.098	0.146	0.114	1.344
3	0.931	0.554	0.148	0.039	0.059	0.097	1.353
4	0.931	0.554	0.148	0.039	0.059	0.097	1.353

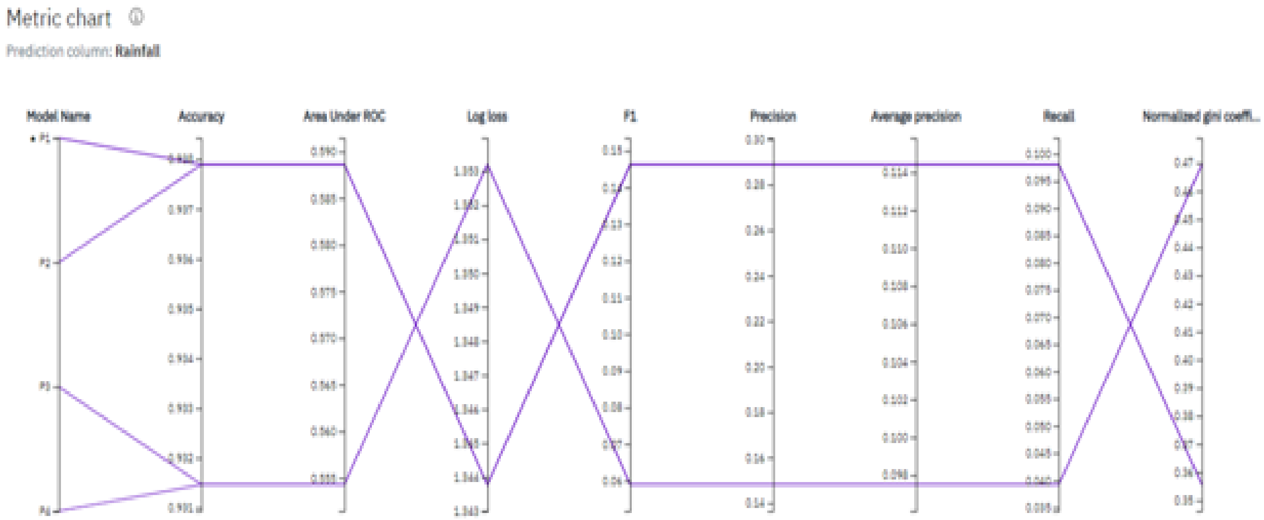

Fig. 19: Metric Chart of Different Pipielines

c. <u>Node RED Software</u>cThis software is an open source resource and is used for application software design for projects in IBM Cloud environment. This provides the user with a graphical environment to design the application flow with minimum coding. This also integrates the UI with the machine learning model and data simulation device in IBM IoT platform. Using this service, User Interface(UI) is designed. Also, flow of the project is designed using this software. Then the simulated sensor device and Random Forest Classifier model is integrated with the UI.

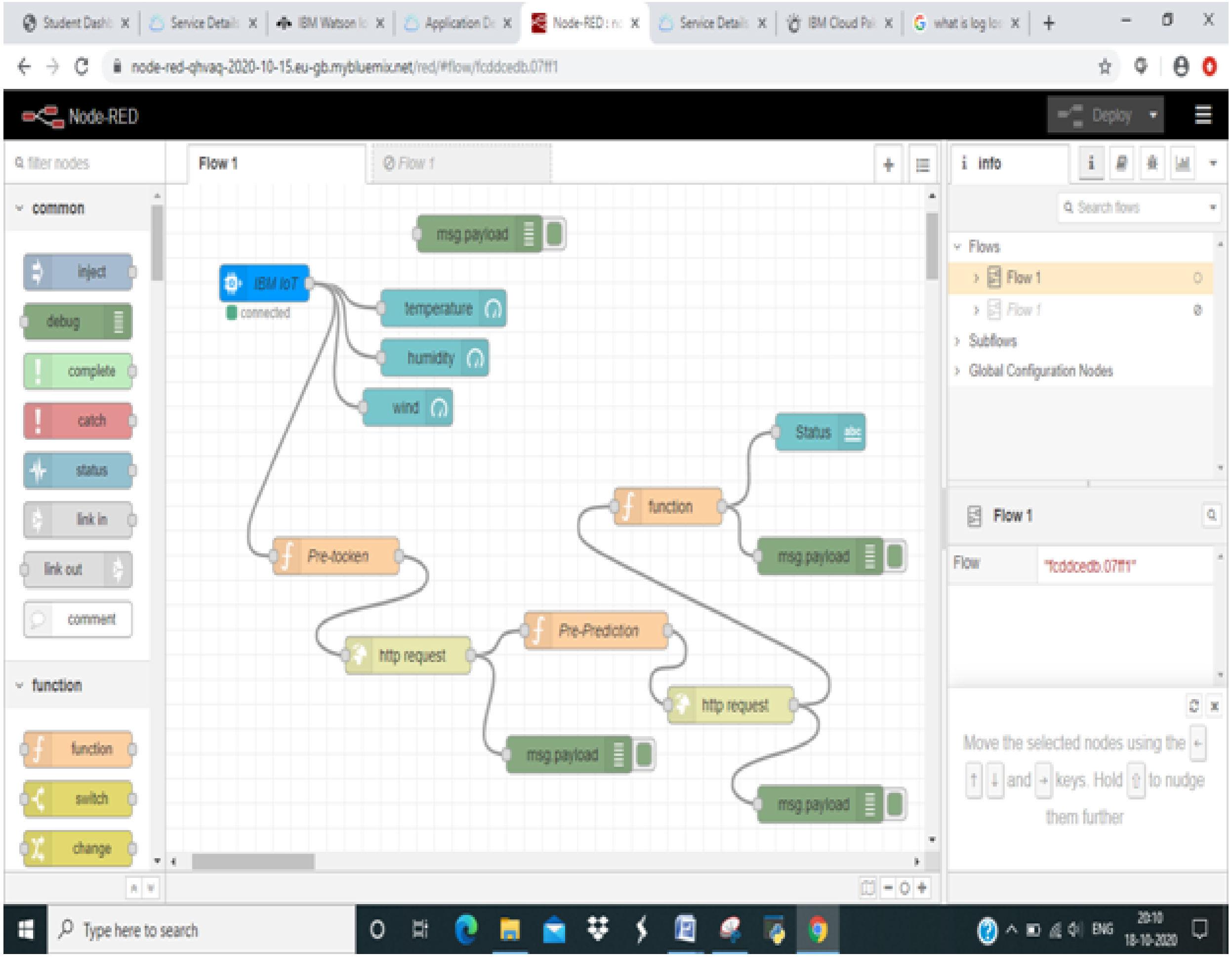

Fig. 20: Flow Diagram of Rainfall Prediction Model

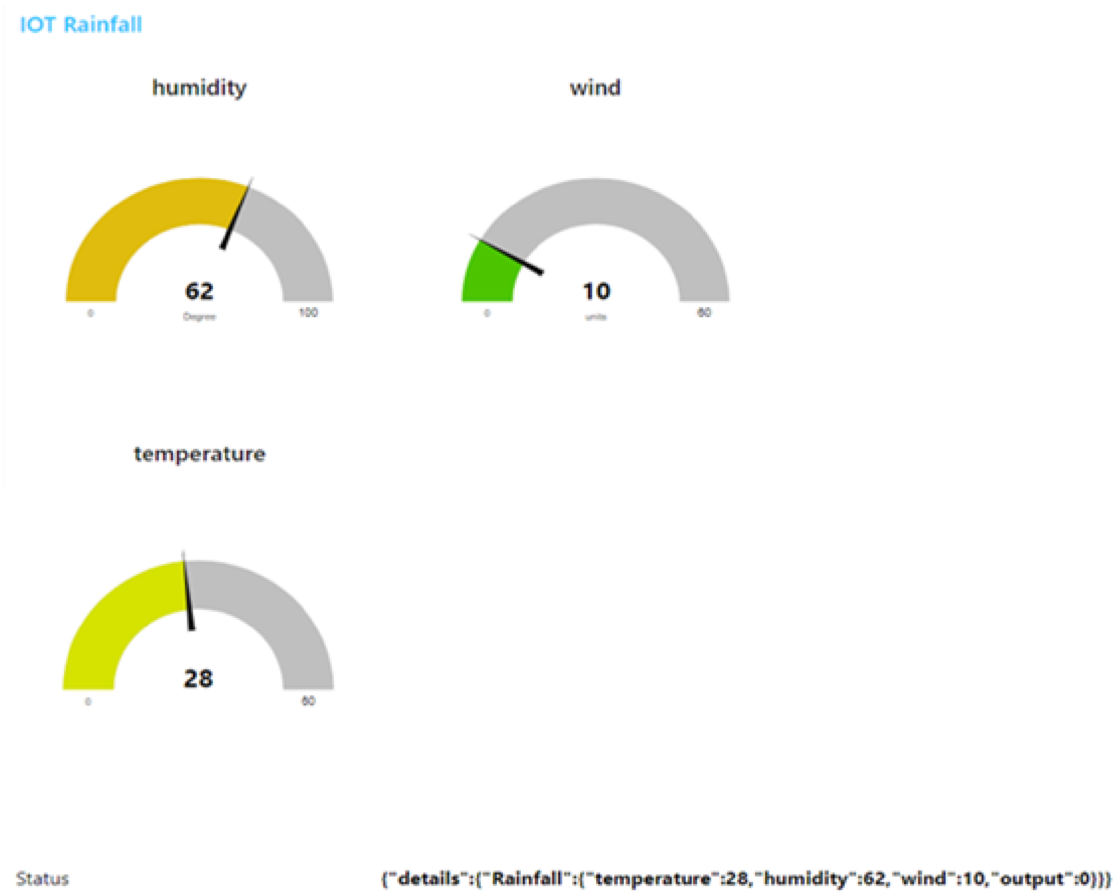

Fig. 21: User Interface of Rainfall Prediction Model

5. Advantages & Disadvantages

Advantages:-

- Farmers can cultivate , harvest and sell crops at right time and hence can avoid loss
- People can plan their activity for the next day.
- Maintainace of electrical wires in streets can be given properly when there is negligible possibility of rain.
- Maintainace to sewerage system can be given properly when there is negligible possibility of rain.
- Government can determine the end of flow of heatwaves over a region and hence the diseases relating to it and hence can decide the next issue of focus.
- Determination of end of problems relating to low level of ground water because the level increases with rainfall.

- Action can be taken for rain water harvesting
- Timely action can be taken for flood management.
- Environment can be saved by planting trees
- Activity in commodity market can be managed properly

Disadvantages:-

- Difficult to exactly predict the rainfall information in a dynamic weather environment
- Expensive to collect all environmental parameters responsible for getting high accuracy in prediction of rainfall
- Huge volume of data needs to be processed for high accuracy which requires more memory space and time. This makes the system costlier.
- Forecasted information for next day may turn false and may bring a lot of problem to people.
- In case of hardware resource failure, people do not get any such information and gets disappointed.

6. Applications

Rainfall prediction information can be used for the following purpose:-

- Irrigation Purpose
- Drainage Maintainance
- Electrical Maintainace
- Cultivation of certain crops
- Solving water problem in society
- Ground Water Level Determination
- Air traffic control
- Safety of marine transit
- Aforestation purpose
- Flood Management and issue alert to people over the region
- Planning of activity for next day by people
- Used by traders in commodity market. For example, traders sell umbrella and raincoat in rainy season.
- Military application

7. Conclusion

IoT sensors are nothing but the devices that collect data from the environment and these data are stored in cloud and machine learning technique is used for analysis of stored data and decision is taken depending on the application. In this work, as a case study, rainfall prediction is taken into consideration. Prediction of rainfall on next day depends on a no. of factors. Here, the factors considered are temperature, humidity and wind velocity. All these data are simulated using simulated device and then random forest classifier with different enhancements are used to train the rainfall prediction model. It is seen that simple random forest classifier lead the pipeline with the accuracy of 0.938 and build time of 01 sec.

8. Future Scope

Accuracy in rainfall prediction depends on the a no. of factors. But it will make the system costly if we include all the factors. Again, rainfall prediction requires time-series data. Storing huge volume of data and analyzing it is also time consuming. So, there is a need of better technique which can handle such issues with rainfall prediction and doing exact prediction.In future, attempt will be made to include more factors in the dataset in order to improve the accuracy of the model.

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APPENDIX

Rainfall Dataset

temperature	humidity	wind	Rainfall
24	65	8	0
26	76	2	0
25	62	10	0
26	65	11	0
26	67	11	0
25	72	10	0
25	66	11	0
25	72	8	0
25	70	5	0
27	73	5	0
26	72	6	0
26	67	5	0
26	71	6	0
27	66	5	0
24	59	5	0
24	61	8	0
24	72	8	0
25	77	10	0
16	100	0	0
26	68	14	0
27	70	10	0
25	72	6	0
23	74	14	0

21	88	14	0
20	85	13	0
22	66	11	0
22	60	5	0
24	59	10	0
20	74	6	0
20	54	19	0
22	53	13	0
22	55	10	0
24	61	6	0
24	60	10	0
26	60	8	0
28	67	3	0
26	70	6	0
27	76	6	0
22	91	11	0
25	64	18	0
24	50	13	0
23	52	11	0
24	40	18	0
23	47	6	0
24	54	2	0
25	63	3	0
24	74	5	0
25	79	5	0
25	56	14	0
27	48	14	0
27	62	6	0
28	64	6	0
27	65	5	0
28	75	10	0
27	67	5	0
28	63	10	0
28	48	11	0
28	57	6	0
28	68	5	0
27	69	3	0

23	90	0	0
28	68	10	0
29	61	13	0
28	61	5	0
29	72	5	0
28	80	6	0
29	78	6	0
28	76	5	0
28	82	3	0
30	72	3	0
28	75	5	0
28	86	3	0
28	83	5	0
33	64	10	0
31	66	3	0
29	76	6	0
28	76	11	0
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31	80	5	0
29	89	5	0
31	83	3	0
31	81	3	0
30	79	2	0
31	76	3	0
30	70	2	0
32	76	3	0
32	76	6	0
30	79	5	0
31	76	10	0
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31	74	3	0
26	85	0	0
32	70	5	0
32	71	2	0
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29	74	2	0
29	80	5	0
28	82	3	0
29	66	3	0
27	70	2	0
27	68	3	0
28	68	3	0
29	74	3	0
28	76	3	0

29	74	3	0
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29	66	8	0
27	66	5	0
27	72	3	0
28	78	2	0
29	75	3	0
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29	69	5	0
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25	61	5	0
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26	66	3	0
26	70	6	0
27	55	6	0
25	69	3	0
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23	69	3	0
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23	74	5	0
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26	77	2	0
25	75	6	0
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22	72	5	0
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24	64	8	0
24	63	8	0
25	73	2	0
28	71	3	0
24	60	11	0
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23	60	5	0
25	60	5	0
23	53	11	0
22	57	3	0
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27	43	6	0
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26	72	3	0
27	71	3	0
27	75	5	0
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28	55	5	0
27	60	5	0
26	75	5	0