Rain Fall Prediction using Ada Boost Machine Learning Ensemble Algorithm

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Abstract:

Every government takes initiative for the well-being of their citizens in terms of environment and climate in which they live. Global warming is one of the reason for climate change. With the help of machine learning algorithms in the flash light of Artificial Intelligence and Data Mining techniques, weather predictions not only rainfall, lightings, thunder outbreaks, etc. can be predicted. Management of water reservoirs, flooding, traffic - control in smart cities, sewer system functioning and agricultural production are the hydro-meteorological factors that affect human life very drastically. Due to dynamic nature of atmosphere, existing Statistical techniques (Support Vector Machine (SVM), Decision Tree (DT) and logistic regression (LR)) fail to provide good accuracy for rainfall forecasting. Different weather features (Temperature, Relative Humidity, Dew Point, Solar Radiation and Precipitable Water Vapour) are extracted for rainfall prediction. In this research work, data analysis using machine learning ensemble algorithm like Adaptive Boosting (Ada Boost) is proposed. Dataset used for this classification application is taken from hydrological department, India from 1901-2015. Overall, proposed algorithm is feasible to be used in order to qualitatively predict rainfall with the help of R tool and Ada Boost algorithm. Accuracy rate and error false rates are compared with the existing Support Vector Machine (SVM) algorithm and the proposed one gives the better result.

Key Words: Precipitable Water Vapour, Machine Learning (ML), Adaptive Boosting, Artificial intelligence

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1. Introduction

Rain, hail and snow – precipitation in any form affect the cricket match or any outdoor activities. Rainfall is the atmospheric occurrence useful for the environment and all living things on the globe. Rainfall prediction can prevent fatalities caused by natural disasters (drought), preventing agricultural products and water levels in reservoirs. Rainfall affects the day-to-day life activities such as traffic control in smart cities and sewer system functionalities. Heavy rainfall creates flood, which is a life threatening event causing dengue and cholera. Flash flooding affects water security and economic stability. These are the reasons why rainfall prediction is the need of the hour. Several hydro-meteorological factors are considered for rainfall prediction. Rainfall prediction using machine-learning algorithms under the influence of Artificial Intelligence and Data mining technique can yield better accuracy.

Statistical forecasting, environmental machine learning, weather data mining and operational hydrology are the various domains involved in the researches carried out for the rainfall prediction. Knowledge Discovery in Databases (KDD) is the core concept of data mining technique. Today's researchers mainly focus on knowledge extraction from time series data. Hourly, daily, weekly, monthly and yearly specific time interval historical rainfall data are used for rainfall prediction. Precipitation prediction is used for rainfall forecasting analysis using time series data mining technique. Strati form, convective rain, orographic rain, tropical storm, thunderstorm and cyclones are the different types of rainfall.

Standard statistical methods and time series data mining techniques are used for climate prediction. Descriptive statistical method, inferential statistical method, associational statistical method, predictive method, prescriptive method, exploratory method and casual method are the various statistical methods used for weather forecasting. Association rule mining, Support Vector Machine, classification, logistic regression, clustering, Navy-Bayes, decision tree and sequential pattern mining are the different types of time series data mining techniques.

R tool is the data-mining tool used for knowledge discovery. A novel Ada boost classifier based ensemble machine-learning algorithm for rainfall prediction is proposed. This method uses multiple learners to be involved in the prediction. Adaptive boosting technique creates strong

classifier from a set of weak classifiers. Supervised machine learning technique is applied on stochastic gradient boosting machines. Ada Boost is used to improve the performance of decision trees on binary classification problems.

The rest of the paper is organised as follows: Section II descries the background information needed for novice reader. Section III includes the existing works related to weather data mining, environmental machine learning, statistical forecasting methods and Artificial Intelligence techniques. Section IV describes the implementation details of the proposed rainfall prediction using Ada Boost machine learning ensemble algorithm. Section V illustrates the results and discussion of the proposed work. Finally, section VI presents the conclusion and future work of the proposed method.

2. Background Study

In this section, fundamental details about weather forecasting are explained for novice readers. Day-today, business and organizational activities depend upon weather conditions. Weather of the earth rotates into several seasons such as summer, autumn, winter, monsoon, spring, etc. Volcanic eruptions, earths' orbital changes, global warming, ocean current and solar variations affect the earth's climate. Pressure, humidity, precipitation, wind, temperature and cloudiness are the six important parameters used to predict the weather. Rainfall prediction techniques are grouped into statistical, numerical, empirical and machine learning.

Data mining techniques such as Navy Bayes (1700s) and regression analysis (1800s) are used to identify patterns in data [1]. United States Department of Commerce released that Doppler RADAR (RAdio Detection And Ranging), Satellite data, Radiosondes, automated surface-observing systems, supercomputers and Advanced Weather Information Processing System (AWIPS) are the tools used by meteorologist to forecast the weather [2]. Weather forecasting is a domain of meteorology that is carried out by grouping dynamic data connected to the present state of weather such as temperature, rainfall, wind, fog, etc. Indian population trust in monsoon season for their agricultural activities. Data mining is an unsupervised machine learning approach used for identifying useful patterns [3].

Traditional weather forecasting techniques include use of a barometer, looking at the sky, now casting, analog technique, Numerical Weather Prediction (NWP) model, ensemble forecasting methods, weather maps and weather satellites. Short range (prediction between 1 to 7 days), medium range (1 to 4 weeks in advance) and long range (1 month to 1 year in advance) are the different groups into which weather forecasting is classified [4]. Indian Meteorological Department (IMD) use effective regression models for long-range weather forecasting.

3. Related Works

In this section, various existing related works in the topics weather data mining, environmental machine learning, statistical forecasting methods and Artificial Intelligence techniques are explained.

3.1 Weather Data Mining

Synoptic, Numerical and statistical methods are the three existing categories of weather prediction. Mohammad Abrar et al. explained the basic principle of all the three methods are the same. Collect input data. Try with either complicated numerical equations or massive statistical interpretations for weather prediction. Climatic observations are received by RADAR, air balloons, sensors, aircraft, ships, etc. [5]. Prediction and classification are some of the data mining technique that uncovers association between independent and dependent variables. Support Vector Machine, Decision Tree and Artificial Neural Networks, Regression and Bayesian Classification are some of the algorithms of prediction and classification [6].

Harsha Dessai et al. proposed a project to forecast the rainfall in Goa using Linear Regression. Naïve Bayes algorithm provided the highest accuracy than other algorithms. Satellite images and weather channels are used by traditional weather forecasting methods, which is an expensive method. Weather data mining forecasting methods are cheaper, easier and provides more accurate prediction results [7]. Rohit Kumar Yadav et al. proposed a weather data-mining model using Hidden Markov Model along with K-means clustering for pattern observation. Supervised and unsupervised machine learning algorithms are used for prediction using the historical data such as moisture, due points etc. Decision trees for classification (ID3) is compared

and the proposed one is found to be the best with regard to various parameters such as memory used, prediction and training time etc. [8].

3.2 Environmental Machine Learning

Ensemble modelling has the concept of combining different modular models for the same activity and integrate them together. S. Monira Sumi et al. proposed a hybrid method with k - Nearest Neighbour (kNN), Support Vector Regression (SVR), Multivariate Adaptive Regression Splines (MARS) and Artificial Neural Network (ANN). The hybrid method yielded more prediction accuracy than individual methods [9]. Chalachew Muluken Liyew et al. proposed a method to predict daily rainfall using Extreme Gradient Boost (XGBoost) algorithm using environmental data sets of different countries. Random Forest (RF), Multivariate Linear Regression (MLR), etc. machine learning algorithms are compared and Pearson Correlation coefficient is used for extraction of environmental features [10].

Bogdan Bochenek et al. proposed an analysis paper by surveying hundreds of weather prediction papers in Google search engine. Machine Learning techniques fall into supervised and unsupervised methods. Deep Learning, XGBoost, Random Forest and Artificial Neural Network fall under supervised machine learning. Principal Component Analysis and k – means clustering techniques come under unsupervised machine learning techniques. Climatology and synoptic meteorology fields apply machine-learning techniques [11]. Atta-ur Rahman et al. proposed a real time prediction method for rain fall using combination of four machine learning techniques such as Support Vector Machine (SVM), k - NN, Naïve Bayes and Decision Tree. Fuzzy logic technique is integrated to improve the accuracy of prediction. In case of life-threatening incidents, a red alert can be issued to the people of smart cities [12].

3.3 Statistical Forecasting Methods

Statistical methods such as univariate and multivariate, which are used to predict the future values using historical data in a certain time period of daily, monthly and yearly, are called as time-series forecasting. Timothy Olatayo et al. proposed a statistical rainfall prediction model using

three different techniques such as Theil's regression, etc. and Fuzzy Time Series (FTS) yielded the minimum Mean Absolute Error (MAE) when compared with other approaches [13]. Intelligent forecasting techniques performed well than statistical methods. Genetic algorithm and Neural Network algorithms performed well in time-series data analysis. Gross Domestic Product (GDP) and growth of India are mainly based on agriculture. Different methods are used for analysing temporal data. Time series data mining is concerned with hydrology, climate forecasting, etc. [14].

S. Kannan et al. proposed a rainfall prediction model for Mahanadi river basin in India using Classification and Regression Tree (CART) using statistical downloading technique of General Circulation Model (GCM). Stochastic weather generators, transfer function based regression techniques and weather – pattern based approaches are the three classifications of statistical downloading techniques. This paper is used for the prevention of Hirakud dam, which is utilised for irrigation and power supply [15]. Javier Diez-Sierra et al. evaluated eight different statistical methods synoptic patterns of Tenerife in Spain. Geopotential Height (GH) and Sea Level Pressure (SLP) are the spatial correlation coefficients taken for prediction. Seventeen rain gauges perform data analysis. Generalized linear models yielded the best results with errors [16].

3.4 Artificial Intelligence (AI) Techniques

Traditional statistical forecasting techniques fail to provide accurate prediction of rainfall due to the nonlinear and dynamic characteristics of weather conditions. Emmanuel Gbenga Dada et al. proposed a rainfall prediction using four Artificial Neural Networks (ANN) models and Elman Neural Network technique gives the best accuracy. Root Mean Square Error (RMSE) minimum error was used for the prediction of weather climate [17]. Vikas Bajpai et al. proposed a rainfall prediction paper in Rajasthan, India using Artificial Intelligence techniques such as Wide Neural Networks and Deep Neural Networks. Rainfall prediction is the essential one for the developing countries like India, which do not have water harvesting and recycling facilities. Data set contains the data from the year 1957 to 2017, which are collected from 33 rain-gauge stations in the districts [18].

Yajnaseni Dash et al. proposed a rain fall prediction method using three artificial intelligence methods such as Extreme Learning Machine (ELM), k – NN and ANN. Kerala collects 2.5 times

higher rainfall than other states of India. Kerala has summer monsoon and post-monsoon rainfall seasons. ELM algorithm provided the best rainfall prediction accuracy than other two methods [19]. Raihan Sayeed Khan et al. proposed a rainfall estimation technique using four different AI techniques on multisource precipitation data sets for Nile basin. Machine learning algorithms yielded minimum random and systematic errors in percentiles. Degree of precision and the resources used for prediction decide the AI model for rainfall prediction [20].

Shilpa Manandhar et al. proposed a rainfall prediction method using Precipitable Water Vapour (PWV) attribute of rainfall data set. These are observed from Global Positioning Signal (GPS) signal delays. Support Vector Machine (SVM) algorithm is used by preparing a weather parameters matrix of (m x n) where m indicates the number of samples and n denotes the weather attributes. The results of this paper is taken for comparing the proposed results [21].

4. Implementation of Rainfall Prediction using Adaboost Machine Learning Ensemble Algorithm

The proposed rainfall prediction work was implemented in a Pentium IV processor, 2 GB RAM, 1 GB disk space, R 2.0.0 and R tool compiled RPMs (red hat Package Manager) for Linux. Rainfall data sets are collected form Indian Government website https://data.gov.in. Data mining process involves three steps as given below:

Step 1: Collect the data set from open repository of Indian hydrological department data.gov.in.

Step 2: Data Cleaning, Data pre-processing, data reduction and feature selection are the various steps in data mining tool.

Step 3: Compare the results obtained from various (SVM and Adaptive Boost) algorithms and choose the best algorithm, which gives the better accurate rainfall prediction and minimum error rate.

Data set is divided into training set and data set by enabling the split option in R tool. For SVM classification, assign kernel as linear and type as “C – classification”. The data mining process is shown in figure 1.

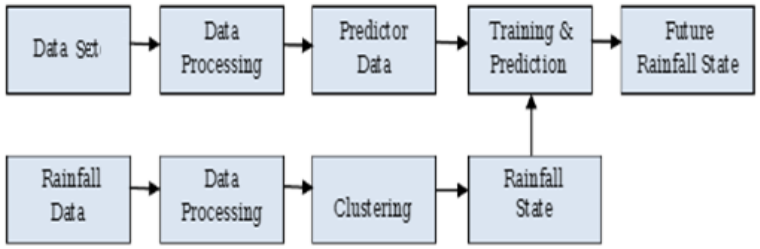

Figure 1. Data Mining involved in the Proposed Work

Hundred and fifteen years old time series historical data collected from indianwaterportal.org from 1901 – 2015 is used for observation. Several attributes such as cloud cover, humidity, wind speed, maximum and minimum temperature, height from sea level, average temperature, wind pressure, wind speed, diurnal temperature, vapour pressure, wet day frequency, wind direction etc. are analysed. The data set contains 4116 records and 18 attributes.

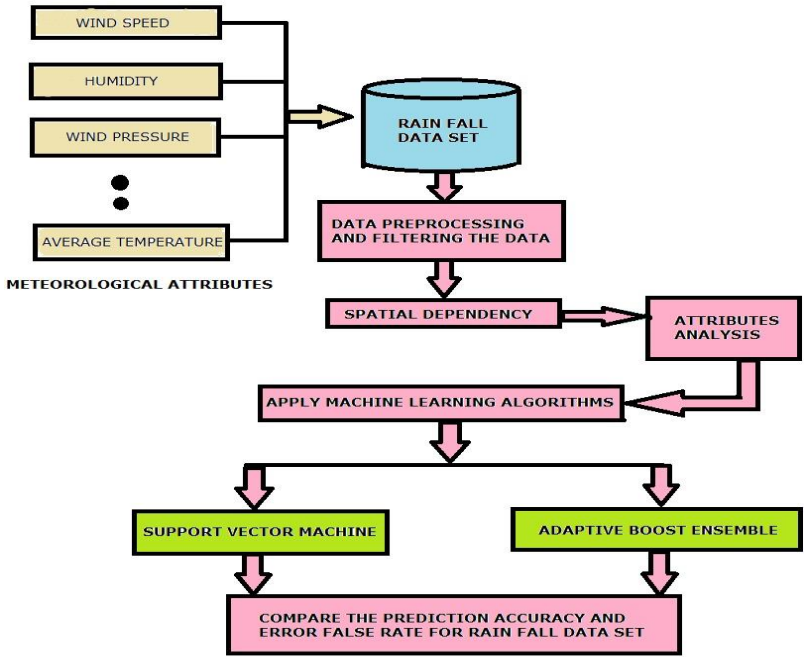

Figure 2. Proposed Frame Work for Rainfall Prediction

Support Vector Machine (SVM) is a classification and regression type supervised machine-learning algorithm. It plots each data item in n – dimensional space. SVM works in Gaussian kernel, Gaussian kernel radial basin function, sigmoid kernel and polynomial kernel. The proposed rainfall data set is given to SVM algorithm for prediction.

Boosting is an ensemble technique that attempts to create a strong classifier from a number of weak classifiers. Adaboost algorithm uses linear regression, decision tree, etc. to classify the problems. This algorithm is implemented in R tool by installing adabag and caret packages. The partial data set, which is read by R tool, is shown in Figure 3.

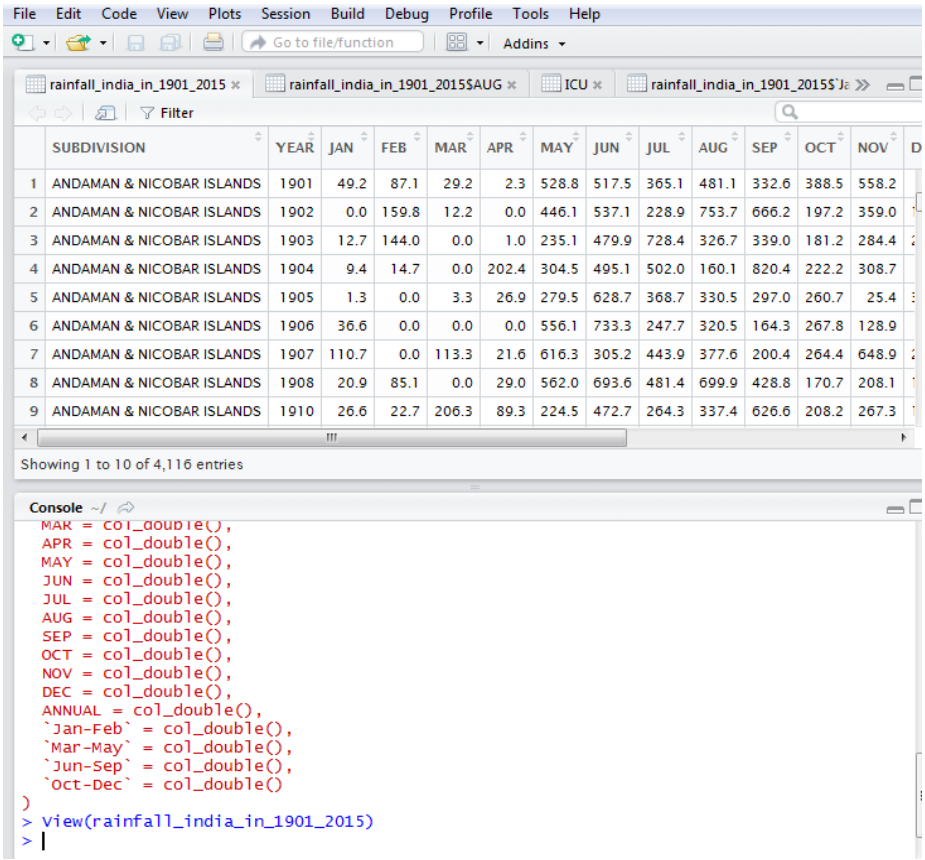

Figure 3. Reading Data set using R Tool

Weak models in AdaBoost algorithm are the decision trees, which are added sequentially and trained. This process continues until an already defined default number of weak learners had

been created or no further improvement can be made on the training data set. Rainfall predictions are made by combining the predictions from multiple models. If the sum is positive, then the first class is predicted. If the sum is negative, then the second class is predicted. Each weak learner calculates a predicted value as either +1.0 or -1.0 for a new input instance. The predicted values are weighted by each weak learner's stage value.

Five weak classifiers may predict the values 1.0, 1.0, -1.0, 1.0, and -1.0 respectively. The model will conclude a prediction value of 1.0 or the first class from a majority vote. Five weak classifiers may have the stage values 0.2, 0.5, 0.8, 0.2 and 0.9 respectively. Calculating the weighted sum of these predictions is an output of -0.8. Now the Adaboost ensemble model will conclude the predicted value of -1.0 or the second class.

Rainfall data set is given into SVM classification and Adaboost classification algorithms in R tool. By comparing the two algorithms, Adaboost provides the best accuracy prediction and less error false rate for rainfall.

5. Results and Discussion

Rainfall prediction accuracy based on plotting position and waiting time for single month is shown in figure 4.

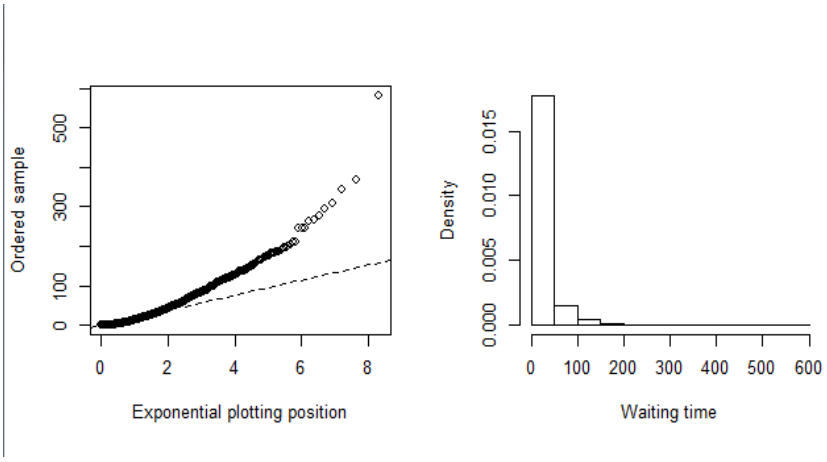

Figure 4. Rain fall Prediction Accuracy for Single Month using R Tool

Rainfall prediction accuracy result for three months from October to December is shown in figure 5.

```
boostr::predictResponseFromWeightedAverage(rainfall_india_in_1901_2015$`Oct-Dec`)
  [1]  980.3  716.7  690.6  571.0  630.8  475.9 1158.9  575.7  629.0  675.4  438.2
 [12]  489.3  613.9 1044.5  696.0  583.3  768.9  785.0  745.9  520.4  895.2  399.9
 [23]     NA  717.0 1152.9  667.1  557.5  678.0  533.3  573.8     NA  565.5  624.4
 [34]  553.2  586.3 1252.5  742.2  561.1  653.9  928.3     NA  667.6  612.1  427.7
 [45]  483.3 1133.4  692.3  552.9  456.7  873.6  693.3  460.3  649.6  703.6  684.5
 [56]  805.0  746.4  584.7  669.8  978.8  817.6  624.1  552.8  556.3 1037.7  839.6
 [67]  857.7  886.1  845.3  797.0  833.7  484.1  371.6  347.0  896.3  761.2  463.8
 [78]  624.9  951.2  685.4  386.5 1021.0  924.3  550.7  525.1  476.2  328.8  555.0
 [89]  341.5  769.2  751.5  459.9  935.4  708.1  594.7  582.0  605.5  432.5  394.2
[100]  877.5  525.2  518.9  636.8  386.9  917.3  601.6  697.5  902.4  704.2  618.4
[111]     NA  262.8  146.7  997.6  103.3  266.4  532.8   61.3  335.2  162.4  379.4
[122]  555.0  661.4  362.0  479.1  241.3  443.5  266.6  240.6   93.6  467.0  273.8
[133]  285.8  171.4  211.3  155.2   41.9  221.3  408.4  217.7  245.1  332.6  224.2
[144]  314.6  449.4  187.1  331.5     NA  204.3  688.9  259.1   36.8  321.5     NA
```

Figure 5. Rain fall Prediction Result for Three Months using R Tool

Horizontal line has a gradient (slope) of 0. Rainfall prediction using Adaboost is shown in Figure 6.

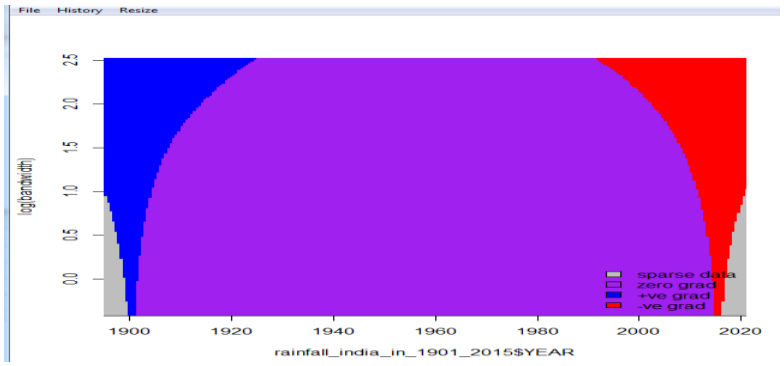

Figure 6. Rainfall Prediction using Ada Boost Algorithm

Prediction results are displayed as s – suspect, p – pathological and n – normal in R tool implementation. If a machine learning classification algorithm is trained, the rainfall prediction model will present the best accuracy with the following conceptual counts:

- TP (True Positive) – Number of rainfall predictions which are correctly classified
- TN (True Negative) – Number of rainfall predictions which are wrongly classified

- FP (False Positive) – Number of rainfall predictions which are correctly misclassified
- FN (False Negative) – Number of rainfall predictions which are wrongly misclassified

Support Vector Machine and Ada Boost Machine learning algorithms are implemented in R tool. Results are compared for the performance parameters of accuracy and error false rate and shown in Table 1. Comparison results for rainfall prediction accuracy is shown in figure 7 and error false rate is shown in figure 8. Adaptive Boost Ensemble machine learning algorithm provided the best accuracy and lesser error false rate than the existing SVM algorithm [21].

Performance Parameters	Support Vector Machine (SVM) Algorithm	Ada Boost Machine Learning Algorithm
Accuracy	79.6%	88%
False Rate	20.3%	12%

Table 1. Rainfall Prediction Comparison

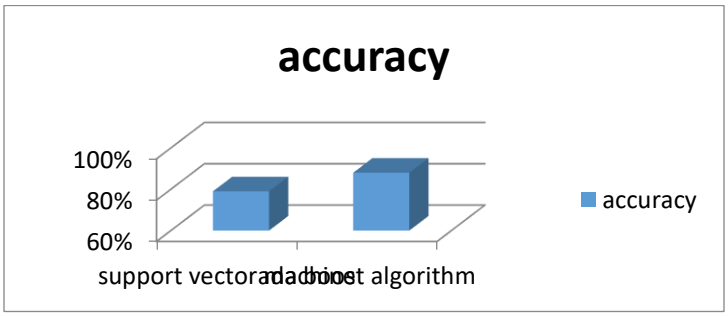

Figure 7. Rainfall Prediction Accuracy Comparison

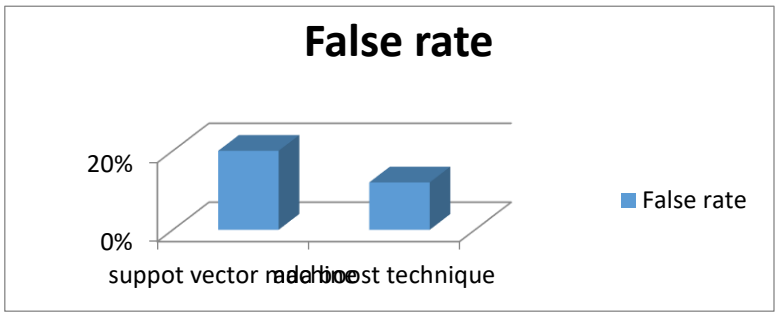

Figure 8. Rainfall Prediction Error False Rate Comparison

6. Conclusion

Many researchers for the rainfall prediction throughout many years carry out many research works. Analysing historical data is difficult and inadequate of technology for rainfall prediction are the existing problems in this research field. Rainfall prediction methodologies depend on the particular data format in which the training model is developed. So training models independent of data formats are needed in future. Clustering, classification, sequence analysis and associations are the various data mining techniques used for grouping relational database. Rainfall prediction on a particular location will not be suitable for different location. A better rainfall prediction mechanism, which is independent of the location, is needed for the current trend in the near future. To conclude the work, AdaBoost ensemble machine learning algorithm provides the highest classification rainfall prediction accuracy with the lowest error false rate compared with SVM algorithm.

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