WEATHER FORECASTING SYSTEM

Project report in partial fulfillment of the requirement for the award of the degree of

Bachelor of Technology

In

COMPUTER SCIENCE & ENGINEERING

Submitted By

RISPARNA CHAKRABORTY	University Roll No. 12018009019659
SMRITI CHOUDHURY	University Roll No. 12018009019176
SAYAN PODDER	University Roll No. 12018009019320
BAISHALI ROY	University Roll No. 12018009019481
PROMITA DEY	University Roll No. 12018009019495
ANKANA GHOSH	University Roll No. 12018009019236

Under the guidance of

PROF. SUDIPTO KUMAR MONDAL

&

PROF. PIYALI CHANDRA

Department of Computer Science & Engineering

UNIVERSITY OF ENGINEERING & MANAGEMENT, KOLKATA

University Area, Plot No. III – B/5, New Town, Action Area – III, Kolkata – 700160.

WEATHER FORECASTING SYSTEM

UNIVERSITY OF ENGINEERING & MANAGEMENT, KOLKATA

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

----------****----------

ABSTRACT

Throughout the ages and with the advancement of technology, weather has been one of the significant part of our lives. Though the main objective has always been the prediction of the figures that conveys us the facts about the weather, which includes temperature check, humidity, rainfall prediction, foresight of natural disasters, etc.

The research paper mainly focuses on data science which is based on datasets and it validates the prediction of various atmospheric factor elements which makes it reliable to get the precise prediction. During the research, while the dataset were worked upon, few inconsistencies were encountered such as missing values in a dataset which were countered by using a pre-processing ML technique known as, “Label Encoding”. The atmospheric factors used for weather prediction were: temperature, rainfall, wind speed, wind direction, humidity, etc. The classifiers used in our research were: Logistic Regression, Linear Regression, K-Neighbors Classifier, Random Forest Classifier, Decision Tree Classifier, Gaussian Naive Bayes Classifier (Gaussian NB), Multilayer perceptron (MLP), K-Means clustering, and Support Vector Classifier (SVC). During the research, the classifiers have derived different accuracies of prediction, with Random Forest and Decision Tree, and Decision Tree, both of which came up with the best results (i.e. 1.0).

The research paper has centralized the observations between two sections. Firstly, illustrating about the classifiers we have put to use and secondly presenting a comparative study between the classifiers aided with a bar graph which makes it easier to visualize the accuracies of different classifiers. The main aim of the research paper lies in the conclusion of finding out the suitable classifier which predicts weather with a greater accuracy on a particular dataset.

KEYWORDS

Weather, Prediction, Dataset, Classifier, Label Encoding, Decision Tree, Bar Graph, Higher Accuracy.

----------****----------

TABLE OF CONTENTS

CHAPTER – 1: INTRODUCTION ..... ***Page No. 1***

CHAPTER – 2: LITERATURE SURVEY

2.1 First Reference Paper (Link Given) ..... ***Page No. 2-3***

2.2 Second Reference Paper (Link Given) ..... ***Page No. 3***

2.3 Third Reference Paper (Link Given) ..... ***Page No. 3-4***

CHAPTER – 3: PROBLEM STATEMENT ..... ***Page No. 4***

CHAPTER – 4: PROPOSED SOLUTION ..... ***Page No. 5***

CHAPTER – 5: EXPERIMENTAL SETUP AND RESULT ANALYSIS

5.1 Experimental Setup ..... ***Page No. 5-10***

5.2 Result Analysis ..... ***Page No. 10-12***

5.3 Classification Report ..... ***Page No. 12-13***

CHAPTER – 6: CONCLUSION & FUTURE SCOPE

6.1 Conclusion ..... ***Page No. 13***

6.2 Future Scope ..... ***Page No. 14***

BIBLIOGRAPHY ..... ***Page No. 14***

CHAPTER – 1: INTRODUCTION

"Can we actually predict the weather, accurately?". To answer that question, we can say, "Yes, we can! (to some extent)". It all depends upon the observation of the surroundings, be it of wind speed, temperature, humidity, etc. In earth, everything is a product of "cause and effect", and weather forecasting is an interesting aspect to it, as it involves predicting weather depending on the "footprints" of the nature, and hence, forecasting is considered to be human kind's one of the greatest invention till date.

So, what is weather forecasting? It is the prediction of the weather depending on the observational data of different atmospheric factors, hence, "fore-casting", to say what will happen before it actually happens, and that alone, is very fascinating. For the forecasting, we look at the atmospheric factors from the past, and in the present. But even with the progress in technology, it is still not accurate enough, the reason being, weather as we know of it, is rampant in it's behaviour that is, it keeps changing. And the randomness of the weather is further influenced by various human-aided factors, one of the effects being that of global warming, which is making the glaciers melt and also making the tropical countries face frequent storms[12].

As weather forecasting involves understanding of atmospheric patterns from the past and from the present, we employed the usage of machine learning algorithms, as it is mainly involved in the understanding and predicting a pattern from a particular dataset. In total, we have used 9 algorithms, out of which, Random Forest and Decision Tree Classifiers have yielded us an accuracy of 1.0. The discussion of different techniques is the main focus of our paper.

Weather forecasting will always be an interesting phenomenon of data science, as it's application is vast, for example, from a household to a cricket stadium, the forecast of rain is always crucial, and hence, a study on weather forecasting is of greater significance, and obviously, very beneficial.

CHAPTER – 2: LITERATURE SURVEY

CHAPTER 2.1:

https://ieeexplore.ieee.org/document/6549158

From this paper, we have gathered the concept of estimating the weather of tropical regions, like in this paper, they have estimated the weather of Thailand, which we already know how difficult it is to estimate weather in the tropics due to sudden occurrence of storms, or, cyclones, which can be accurately corrected by employing satellite passive millimeter-wave observations. So, they have implemented the usage of AMP (AMSU MIT PRECIPITATION) as AMSU observations are very similar to that prevalent in the tropics, specifically AMSU-A and AMSU-B aboard NOAA-16 satellite and corresponding AMSU estimates of precipitation parameters. On our paper, we have implemented various machine learning algorithms of both supervised as well as unsupervised, and also, classifiers belonging to regression, neural network types, etc. to predict the weather, which is dependent on a particular dataset. So, by referring to this paper we have incorporated the scope of our research in future if we make our predictions dependent on the tropical lands, this paper would be of great aid.

- The main objective of this paper and our paper is the same, i.e., to develop a Weather Forecasting System. We have used a different approach to achieve our goal. Data Science and Machine Learning plays an important role in our research work. But we got the basic idea about how to determine weather in general with the use of different attributes.

- In this research paper they have analysed the result using graphs, Histograms and charts. In our research work we have also displayed and analysed the output through Bar graphs, grids, tables and charts.

- Our research work demonstrates how machine learning and Data mining can be used to forecast weather in an efficient way. And, this paper mainly focuses on forecasting weather for tropical climate. But the goal remains the same and the information related to tropical weather helped us in determining weather altogether.

- The future scope of weather forecasting utilizing satellite passive millimeter-wave and using machine learning is huge.

- With the rise of technology, the future work on this area is going to be challenging but not impossible. More the data is gathered related to weather and atmosphere conditions, more the prediction will be accurate in the future.

CHAPTER 2.2:

https://ieeexplore.ieee.org/document/8862451

Machine learning is predominantly an area of artificial Intelligence which has been a key component of digitalization solutions that has caught major attention in the digital arena. In this project various popular machine learning algorithms, which are used frequently are reviewed. Using a dataset we also derived the accuracies of the machine learning algorithms and also derived the most efficient algorithm used in this project. We also highlighted the merits and demerits of the machine learning algorithms from their application perspective to aid in an informed decision making towards selecting the appropriate learning algorithm to meet the specific requirement of the application.

- Throughout the project, we have used various datasets for checking the accurate weather forecast of the location known as "Canberra" (Australia), based on the weather predicting data of consecutive 5 days.
- We have analyzed the datasets at different interval of times to make the results more specific.
- A total of 9 algorithms were used, including Decision trees, K-NN, Random Forest algorithms, and others, which were useful in predicting temperature, rainfall, wind speed, wind direction, and humidity, among other things.
- The various data which were obtained during the project are tallied with each other which initially help us to predict the weather accurately to maximum extend.
- The status of the atmosphere for a certain area can be forecasted in the near future using machine learning. As a result, the scope of future work reveals how far the research area will be investigated.

CHAPTER 2.3:

https://ieeexplore.ieee.org/document/8389719

Nowadays, Analysis of atmosphere conditions has become a vital process; where in prediction of state weather for a future time is made based on location. Weather prediction is gaining up ubiquity quickly in the current period of Machine learning and Technologies. It is fundamental to foresee the temperature of the climate for quite a

while. To improve the performance of system, collection of data related to current state of the atmosphere is important.

- Total 9 algorithms were used like Decision trees, K-NN, Random Forest algorithms,etc which were an integral asset utilized in several atmospheric prediction works like temperature, rainfall, wind speed, wind direction, humidity, etc.In this paper, a simple approach for weather prediction of future years by utilizing the past data analysis is proposed by the Decision tree and Random forest algorithm calculations, showing the best accuracy result of these two algorithms.
- Weather prediction plays a significant job in everyday applications and in this paper the prediction is done based on the temperature changes of the certain area known as “Canberra” (Australia). Finally, using these algorithms in this work we can predict whether the temperature increases or decreases, is it a rainy day or not, etc. The dataset is completely based on weather predicting data for the preceding 5 days. A study further ends by comparing different techniques for weather forecasting.
- The main moto of this study is to compare and identify a precise weather forecasting model. Weather prediction will be effective if, Input Data of years is taken instead of just 2–3 days. Thus, if we train the system by considering huge data the performance will be more effective - “Better the training, better the result”.

CHAPTER – 3: PROBLEM STATEMENT

In this study, we have primarily focused on the weather forecast for the location known as "Canberra" (Australia), which is based on weather predicting data for the preceding 5 days. We have considered the record of the data which includes minimum temperature, maximum temperature, rainfall, evaporation, sunshine, wind gust direction, wind direction, wind speed, humidity, pressure, cloud and amount of rainfall. The various data are tallied with each other which initially help us to predict the weather accurately to maximum extend.

In our project, the ultimate aim is to deduce weather with the help of various machine learning algorithms, where, we are obtaining data from a particular dataset. We know that weather forecasting on itself is an interesting phenomenon, because, we are determining how the weather is going to behave in future based on certain situations, but it is made completely possible (almost) with the help of various algorithms, both supervised and unsupervised.

CHAPTER – 4: PROPOSED SOLUTION

Based on the accuracy obtained from the algorithms, we propose both Random Forest Classifier and Decision Tree Classifier as they have the highest accuracy values of 1.0.So, the outcome proves that above algorithms are efficient and accurate in predicting the weather conditions.

We will not use K-Means clustering Algorithm as it has the lowest accuracy of 0.46.

CHAPTER – 5: EXPERIMENTAL SETUP AND RESULT ANALYSIS

CHAPTER 5.1: EXPERIMENTAL SETUP

There are several classifiers available. The following classifiers are discussed here.

Logistic Regression

Logistic Regression is a supervised learning algorithm that is used to predict or calculate the observations to a discrete set of classes. Basically, it is used to classify observations into different categories. Therefore, its output is discrete in nature. Logistic Regression is also called Logit Regression. It is based on the Maximum Likelihood Estimation (MLE) approach.
Logistic Regression algorithm works by implementing a linear equation with independent variables to predict or calculate a response value. This predicted response value, denoted by z and then converted into a probability value that lies between 0 and 1. We use the sigmoid function in order to calculate values to probability values and this sigmoid function then maps any real value into a probability value between 0 (stands for failure/no) and 1 (stands for success/yes). Mathematically, a logistic regression model calculates P(Y=1) as a function of X[1]. It is one of the most simple and versatile classification algorithms which is used to solve classification problems.

Linear Regression

Linear regression is also a supervised machine learning algorithm which is used to solve regression problems, and provides a continuous output. It is a linear model, which means that it assumes that the input and output variables have a linear relationship. Linear regression can be understood in two forms: (a) Simple Linear Regression, and, (b) Multiple Linear Regression. For our paper, we have employed Multiple Linear Regression, with a mean squared error (M.S.E.) of about 0.2568, which is acceptable but other classifiers have yielded much better accuracies (or, lesser error). For a better

understanding, we are going to discuss about Simple Linear Regression. Here, we are considering regression y on x, such as,

$$y=b_0+b_1x,$$

where,

y is the target value, x is the estimator value, b_0 is the intercept, and b_1 is the slope.

Hence, in this regression equation, we predict the pattern of y using the independent value x, and hence, can be plotted on a graph giving us a best fitted line. But, while working with linear regression and also with a large dataset, we have to keep in mind that the dataset is not collinear, that means, higher collinearity would over-fit our data, and hence, less accurate prediction. The main focus of linear regression is to find a best fitted line for a particular given dataset.

K-Neighbors Classifier

K-Nearest Neighbors (KNN) is a standard machine-learning method which is basically used to describe classification and regression problems. It is a multipurpose algorithm also used for imputing absent values and resampling datasets. The name, K Nearest Neighbor considers K Nearest Neighbors or the Data points to predict the class or continuous value for the new Datapoint[3].

The nearest neighbors basically means the data points that have least distance in feature space from our new data point. And K denotes the number of such data points which are considered in our implementation of the algorithm. Hence, distance metric and K value are two important concerns while using the KNN algorithm. Euclidean distance being the most prevalent distance metric. For expecting class/ continuous value for a new data point, it studies all the data points in the training dataset. Then finds new data point's 'K' Nearest Neighbors from feature space and their class labels or continuous values. Then for,

Classification: Here, the class label which is allotted to the majority of K Nearest Neighbors from the training dataset is considered as a predicted class for the new data point.

Regression: Mean or median of continuous values allotted to K Nearest Neighbors from training dataset is a predicted continuous value for the new data point.

Random Forest Classifier

Random Forest algorithm is a well-known machine learning algorithm. It belongs to the Supervised Machine Learning technique. It is used for classification as well as Regression problem in Machine Learning because of its simplicity and diversity. Random forest consists with multiple decision trees and merges them together and takes the average to improve the accuracy of the dataset and stable prediction. If the number of trees in the forest increases that leads to higher accuracy. Random forest takes multiple trees for prediction of the dataset, some decisiontrees may predict the correct output but some may not predict the correct output. We should use Random Forest algorithm because as compared to other algorithms random forest algorithm takes less time to train data. Accuracy of random forest algorithm is high. Even if on large data set it runs efficiently. When a large proportion of data is missing it maintains accuracy. In banking sector, marketing sector, in the field of medicine we use random forest algorithm.

Decision Tree Classifier

Decision Tree is a unique supervised learning method in machine learning. The special thing about it is that it can be used for both regression and classification solving problems. But in the area of research field mostly classification is preferred. So it is a tree-based classifier as the structure is similar to that of the tree. The attributes of the dataset is represented by the internal nodes, branches represent the decisions and each leaf node represents result. Decision nodes are used for decision making and leaf nodes are the outcome of the decisions.

Here in this research work Decision Tree Classifier is used in an efficient way. Firstly, the unstructured dataset is processed and then it is trained so that the algorithm can work on it without producing any error. The Decision Tree Classifier produces an accuracy of 1.0 exactly. So, in this case as the accuracy is maximum it is one of the most important algorithms in this research paper.

K-Means Clustering

K-Means Clustering is one of the simplest unsupervised machine learning technique. It generally solves all the clustering problems that means it groups the un-labelled dataset into groups called as clusters. In the word “K-Means Clustering”, the k stands for the number of clusters which is predefined that needs to be created in the ongoing process. It is considered as an iterative algorithm that groups dataset into k different clusters in such a

way that each group belongs to only one group with similar properties. The advantage of this algorithm is that it can work on untrained or un-labelled dataset.

Out of all the algorithms used, the accuracy of this method is lowest. It yields an accuracy of 0.46 which is not considered a good result as compared to the other techniques that performed really well.

Gaussian Naive Bayes Classifier (Gaussian NB)

The Naive Bayes classifier consists of two words that are Naive and Bayes which means-

Naive –Naïve means occurrence of a certain property does not depend on the occurrence of other property.

Bayes- As it is dependent on Bayes theorem. To determine the probability of a hypothesis with previous information Bayes theorem is used.

Thus, the classifier is known as Naïve Bayes.

It is a supervised machine learning algorithm which is used to classify Text and make prediction very quickly.

Classifying articles, sentiment analysis, filtration of spam are some examples of this classifier.

Many types of Naïve Bayes models are present in machine learning.

Gaussian, Multinomial, Bernoulli etc.

The Gaussian Naïve Bayes model takes that properties follow a normal distribution. Instead of discrete values if predictors take continuous values, then the model assumes that these values are sampled from the Gaussian distribution.

Multilayer Perceptron

Multilayer perceptron, the concept behind all of the other neural network concepts, is referred to as a "feed forward" artificial neural network (or, ANN) which provides output depending on the set of inputs (or, data) given. It is consisting of an input layer, an output layer, and hidden layer (or, layers) depending on the requirement. A general example of multilayer perceptron can be of the time when we search for any query on Google.com,

we are interested only on the output, without bothering about any Google algorithms and functionality. Such is the example of multilayer perceptron.

Here, inputs in multilayer perceptron are assigned with “weights”, where weights are initialized with small random values. Then, the weighted inputs are added and passed to the hidden layers. In the hidden layers, we have anactivation function, where, the weights are “mapped” to its respective outputs. Activation function consists of: ‘identity’, ‘logistic’, ‘tanh’, and, ‘relu’, out of which, ‘relu’ is selected as the default. Hence, we can understand that, multilayer perceptron works on the cumulative effect of all of the factors that are involved (example being, activation function, assignment of small random values to inputs as “weights”, etc.). For our paper, we have employed activation function as logistic, which means that the function takes any value between 0 and 1, and, we yielded an accuracy of 0.83, which suggests that multilayer perceptron is able to predict the pattern to some extent.

Support Vector Classifier (SVC)

Support Vector Classifier or SVC is a popular Supervised Machine Learning algorithm. It is used to Classify Regression problems. Previously it is used to Classify Machine Learning problems. SVC is used to create best decision boundary that can separate n- dimensional space into classes. We call this decision boundary as hyperplane. SVC chooses the extreme points/vectors that helps to create the hyperplane. We call these extreme cases as support vectors, and the algorithm is named as Support Vector Classifier. SVC algorithm is used to detect face, classify images, categorize text etc.

SVC is mainly two types.

a. Linear SVC, b. non-linear SVC.

Linear SVC is used to separate linear data, which means if a dataset can be classified into two classes by using a single straight line, this type of data is called as linearly separable data, and classifier which is used to classify the data is called as Linear SVC classifier.

Non-Linear SVC is used in case of non-linearly separated data, which means if a dataset cannot be classified by using a straight line, then such data is termed as non-linear data and nonlinear classifier is used. [11]

Above specified classifiers are compared by calculating their accuracy, which classifiers predict the weather with greater accuracy on a particular dataset. All the classifiers are run

in Jupyter Notebook. The main motive of this comparative analysis is to compare the accuracies of different machine learning models and identify a precise weather prediction model using those classifiers[2].

To do the comparison following steps are followed:

Step-1: First we import the data set downloaded from the Kaggle website.

Step-2: Then we are fetching the data from the dataset and named the columns by their feature name.

Step-3: After that we split arrays or matrices into random train and test subsets.

Step-4: Next, we import the classifiers module and create objects.

Step-5: Afterward, we fit our model on the train set using the fit function and perform prediction on the test set using predict function. X_train is the training data set and Y_train is the set of the labels to all the data in X_tain.

Step-6: Then we are calculating the accuracy of our calculation with the help of the accuracy function.

Step-7: In this way, we find all the classifiers' accuracy and then we make a comparison to see which classifiers give the higher accuracy of weather prediction.

Step-8: Then we are plotting a bar graph between the classifiers and accuracies which makes it easier to visualize the accuracies of different classifiers.

CHAPTER 5.2. RESULT ANALYSIS

After performing all the steps we find that some of the classifiers calculate the accuracy and some of them calculate the error.

Highest Accuracy: Among all the classifiers Random Forest Classifier and Decision Tree Classifier give the highest accuracy that is 1.0.

Intermediate Accuracy: Gaussian Naive Bayes Classifier (Gaussian NB), Logistic Regression, K-Neighbors Classifier, Support Vector Classifier (SVC) and Multilayer perceptron (MLP) give the intermediate accuracy that is 0.98, 0.96, 0.89, 0.83, 0.83 respectively.

Lowest Accuracy: K-Means clustering gives the lowest accuracy that is 0.46.

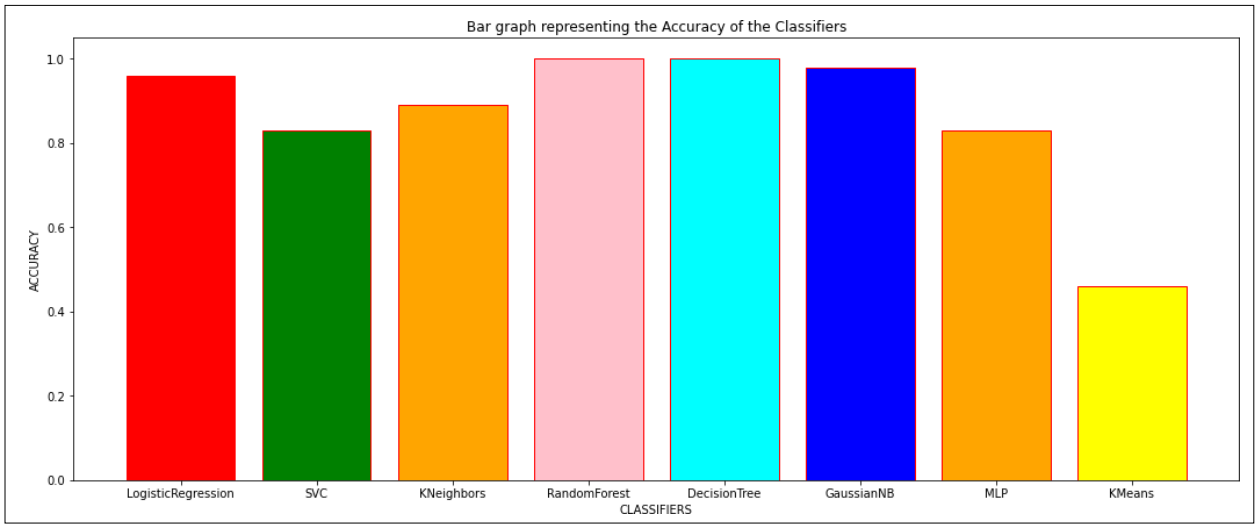
Table1. COMPARATIVE ANALYSIS

Classifiers Name	Accuracy	Status
Random Forest Classifier	1.0	Highest
Decision Tree Classifier	1.0	
Gaussian NB Classifier	0.98	Intermediate
Logistic Regression	0.96	
K-Neighbors Classifier	0.89	
Support Vector Classifier	0.83	
Multilayer perceptron	0.83	
K-Means clustering	0.46	Lowest

Now we make a comparative study of the accuracies obtained from different Machine Learning models, aided with a bar graph. To draw the bar graph we import the matplotlib function module.

The X-axis of the bar graph represents the classifiers and the Y-axis of the bar graph represents the accuracies of the classifiers. Here I used different colors to represent different types of classifiers.

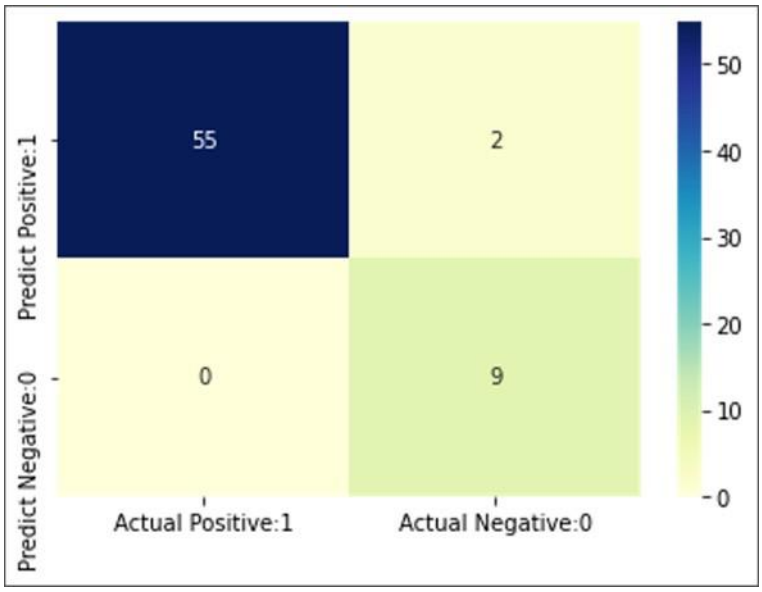
Graph1.Classifiers VS Accuracy



In this plot, we can clearly see that Random Forest Classifier and Decision Tree Classifier have the highest accuracy value. Besides, K-Means clustering Algorithm has the lowest accuracy value.

CHAPTER 5.3.CLASSIFICATION REPORT

A confusion matrix is a method which is responsible in abridging the execution of an order calculation. Here, more values signify darkish colours, and fewer values signify faded colours.



- ***Accuracy:*** It is one of the method which is used to evaluate classification models. Accuracy=((TP+TN)/(TP+TN+FP+FN))
- ***Precision:*** It determines how correct it is when the model predicts positive. Precision = TP / (TP + FP) . The Precision is 0.9649.
- ***Recall:*** It tells how much the false negative cost is.

  Recall = TP / (TP + FN). The Recall here is 1.0000.

- ***Error rate:*** It is the sum of incorrect cells of the table divided by all cells of the table. Error = ((FP + FN)/(TP + TN + FP + FN)). The Error rate is 0.0303.

	precision	recall	f1-score	support
0	1.00	0.96	0.98	57
1	0.82	1.00	0.90	9
accuracy			0.97	66
macro avg	0.91	0.98	0.94	66
weighted avg	0.98	0.97	0.97	66

CHAPTER – 6 : CONCLUSION & FUTURE SCOPE

CHAPTER 6.1: CONCLUSION

This research paper demonstrates that how machine learning and data mining can be used to forecast weather in an efficient way. It works with several algorithms to predict weather condition. The unstructured dataset is assembled and also analysis is performed thoroughly on this observational dataset using technique like label encoding to get the desired result. This whole process arranges the given information into various models after the training of the dataset. Thereafter comparison of the accuracies produced by the algorithms is done by the help of a bar graph. It helps to visualize the outcome of the research paper more clearly and also it can decide the relationship that exists between the algorithms. The outcome is interesting as out of many algorithms the best performance is of the two algorithms each with accuracy 1.0. With the use of machine learning, the state of the atmosphere for a given location can be predicted in the near future. So, the scope of this work in the future explains the extent to which research area will be explored. The main idea of this research work is to forecast the weather by using scientific knowledge and technology. With the rise of technology, the future work on this area is going to be challenging but not impossible. More the data is gathered related to weather and atmosphere conditions, more the prediction will be accurate in the future.

CHAPTER 6.2: FUTURE SCOPE

- More weather models started integrating with the advancement of machine learning and weather forecasting will become very accurate.
- Machine learning has so much scope & potential in global nowcasting. Global nowcasting is a relatively new addition to weather forecasting.
- Weather Forecasting doesn't help in our daily life but it has deeper impact in case of disaster management, food security, agriculture etc.
- Many new technologies like Machine learning are helping meteorological experts to give better information to predict agricultural output and natural disasters.
- Another future scope can be inferred, that is, we can implement our very own classifier model to determine weather forecasting, and that on it's own will be much more useful.

BIBLIOGRAPHY

While making this paper, these following research papers were referenced. They are as follows:

1. https://ieeexplore.ieee.org/document/8938211

2. https://ieeexplore.ieee.org/document/8389719/authors#authors

3. https://ieeexplore.ieee.org/document/8993316

4. https://ieeexplore.ieee.org/document/9215440

5. https://ieeexplore.ieee.org/document/8862451

6. https://ieeexplore.ieee.org/document/5212227

7. https://ieeexplore.ieee.org/document/8544326

8. https://ieeexplore.ieee.org/document/8588666

9. https://ieeexplore.ieee.org/document/1382229

10. https://ieeexplore.ieee.org/document/8819643

11. https://ieeexplore.ieee.org/document/9351749

12. https://ieeexplore.ieee.org/document/6549158