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Weather Forecast Prediction: An integrated Approach For Analyzing And Measuring Weather Data

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Abstract :

To predict something we need some background study to understand the pattern. Weather forecasting is the practice of predicting the state of the atmosphere for a given location based on different weather parameters. On earth, every phase of human life is influenced by nature. As we cannot avoid the natural changes and conditions, we have chosen to minimize their effect on our lives. Therefore, to achieve this we need to know the weather conditions beforehand, to make things work according to the changes in the environment. Weather forecasting is the use of science and technology to predict the condition of the weather for a given area. It is one of the most difficult issues the world over. This project aims to estimate the weather by utilizing predictive analysis. For this reason, analysis of various data mining procedures is needed before apply. This paper introduces a classifier approach for prediction of weather condition. Agriculture is the field that is most influenced by the weather. This paper explores the details of this project. Weather forecasts are made by gathering data about the current state of the atmosphere. Accurate weather forecasting has proven to be a challenging task for meteorologists and researchers. Weather information is essential in every facet of life like agriculture, tourism, airport system, mining industry, and power generation. Weather forecasting has now entered the era of Big Data due to the advancement of climate observing systems like satellite meteorological observation and also because of the fast boom in the volume of weather data. So, the traditional computational intelligence models are not adequate to predict the weather accurately. Hence, deep learning-based techniques are employed to process massive datasets that can learn and make predictions more effectively based on past data. The effective implementation of deep learning in various domains has motivated its use in weather forecasting and is a significant development for the weather industry. This paper provides a thorough review of different weather forecasting approaches, along with some publicly available datasets.

Keywords: Weather, Weather Predictions, Forecast, Forecasting Models, Weather data, Forecasting methods and applications

Introduction :

Weather forecasting is the scientific prediction of the state of atmospheric conditions such as temperature, humidity, dew point, rainfall, and wind speed based on reliable data. Barometers, radar, and thermometers are used to collect data for weather prediction. External factors such as current weather conditions, data of previous weather patterns, tracking the motion of air and clouds in the sky, finding and verifying changes in air pressure are essential in forecasting weather. Accurate weather forecasting information is crucial in keeping people and property safe from threats of tornadoes, floods, and major storms. Various sectors like Business, Tourism, Sports, Agriculture, Mining, Power, Food Industry, Airport, and Naval systems depend heavily on accurate weather forecasting. In agriculture, prior information about weather helps farmers to take necessary decisions to improve their crop yields. The main problem we want to talk about in this research paper is that predicting the weather accurately is not easy. Weather is influenced by so

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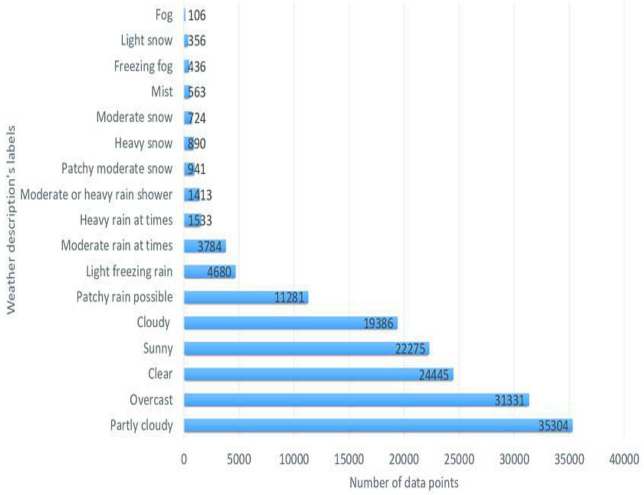
many complicated things happening in the atmosphere that it's hard to predict exactly what will happen. This means that sometimes our weather forecasts aren't as accurate as we'd like them to be. One big challenge is using computer models to predict the weather. But because the atmosphere is so complex, it's tough for the models to include every little detail, which can make the predictions less accurate. Another problem is getting all the data we need. Weather forecasts rely on information from weather stations, satellites, and radars. Sometimes, there are delays in getting this information or gaps in the data, which can make it harder to make good forecasts. It involves analyzing and interpreting data gathered from various sources, such as weather stations, satellites, radars, and numerical weather prediction models, to generate forecasts that inform the public and various industries about expected weather conditions, including temperature, precipitation, humidity, wind speed, and atmospheric pressure. In this research paper, we will look closely at these problems and try to find solutions to make weather forecasting better. By understanding the challenges and finding ways to improve, we hope to make weather forecasts more accurate and reliable. This will help us be better prepared for any weather changes and keep us safe from extreme weather events.

Weather Data Collection and Preparation

To effectively evaluate the performance of the classifiers in weather prediction, weather data were collected. For this purpose, the Weatherstack API (**https://weatherstack.com**,)was used as it readily collects a vast range of weather data from different areas with high reliability, consistency, and accuracy, ensuring that the collected datasets are accurate and up-to-date. It is also compatible with Python, the employed programming language in this study. The selection of these cities aimed to capture a variety of weather conditions, reflective of the geographical disparities within Sweden. Each of the three collected datasets contains 14 input features (or attributes) and an output. The output shows the actual weather condition, such as sunny, cloudy, or clear sky, and the input features show the variables that affect the weather conditions. The employed input features are time, temperature, pressure, humidity, wind speed, wind direction, wind degree, perception, visibility, cloud cover, heat index, dewpoint, windchill, and wind gust—factors that collectively influence the weather conditions. While the first dataset contains weather data spanning from 2009 to 2022, the latter two contain weather data for April 2023. It is observed that partly cloudy weather occurs most frequently, with 35,304 samples, followed closely by overcast, with 31,331 samples, and clear, with 24,445 samples. On the other hand, fog occurs the least frequently in the dataset, with only 106 samples.

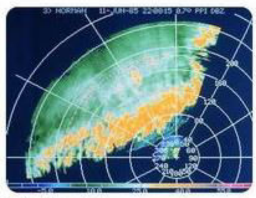


In weather forecasting, data collection has been divided into two categories namely: 1] Upper-air weather observations 2] Surface weather observations


Weather Station


Weather Balloon


Weather Satellite


Weather Radar

Upper-air weather observations

Upper-air weather observations play a crucial role in understanding and forecasting weather patterns in the Earth's atmosphere. These observations provide vital information about temperature, humidity, wind speed, and wind direction at various altitudes, aiding meteorologists in analyzing atmospheric conditions and predicting weather changes. Upper-air weather observations involve launching weather balloons equipped with instruments called radiosondes into the atmosphere. Radiosondes are small electronic devices that measure atmospheric parameters as they ascend through the air. It helps identify temperature variations with altitude, known as the vertical temperature profile. Upper-air weather observations significantly contribute to the initialization of numerical weather prediction models. By assimilating upper-air observations into these models, forecasters obtain better starting points for simulations, resulting in more accurate and reliable weather forecasts.

Surface weather observations:

Surface weather observations are essential for monitoring and understanding current weather conditions at Earth's surface. These observations provide crucial data on temperature, humidity, wind speed, wind direction, atmospheric pressure, and precipitation. They serve as the foundation for various weather analyses, forecasts, and severe weather warnings. Surface weather observations are typically conducted at weather stations, which are strategically located worldwide.. The most common instruments include:

1. **Thermometers**: Thermometers measure air temperature, which is a key parameter for understanding weather patterns and forecasts. Standard mercury or digital thermometers are commonly used to record temperature readings.

2. **Hygrometers**: Hygrometers measure humidity, which is the amount of moisture present in the air. Various types of hygrometers, such as psychrometers or electronic sensors, measure relative humidity or specific humidity.

3. **Anemometers**: Anemometers are used to measure wind speed, providing information about air motion at the Earth's surface. Cup anemometers or sonic anemometers are typically used to record wind speed and sometimes wind direction.

4. **Barometers:** Barometers measure atmospheric pressure, which is crucial for understanding changes in weather **patterns**. Mercury barometers or aneroid barometers can be used to record atmospheric pressure readings.

5. **Rain Gauges:** Rain gauges measure the amount of precipitation that has fallen at a specific location over a given timeframe.

Numerical Weather Prediction

Numerical Weather Prediction (NWP) is a method of forecasting weather conditions using mathematical models and computer simulations. NWP combines atmospheric physics, thermodynamics, fluid dynamics, and observational data to produce accurate and detailed weather forecasts. Linacre and Geerts (1997) define Numerical Weather prediction (NWP) as a simplified set of equations called the primitive equation used to calculate changes of conditions.

To represent an NWP model in its simplest form, we can write:

$$\Delta A/\Delta t = F(A)$$

where ΔA gives the change in a forecast variable at a particular point in space

ΔT gives the change in time (how far into the future we are forecasting) F(A) represents terms that can cause changes in the value of A.

Future values of meteorological variables are solved for by finding their initial values and then adding the physical forcing that acts on the variables over the time period of the forecast. This is stated as

$$A^{forecast} = A^{initial} + F(A)\Delta t$$

Numerical Weather Prediction (NWP) models are mathematical models that use complex algorithms to simulate and predict weather patterns. These models use data from various sources, including upper-air observations, surface observations, radar data, satellite imagery, and more. The basic principle behind NWP models is that they use mathematical equations to simulate the behavior of the atmosphere. These equations describe how air moves, how moisture is transported, and how heat is transferred within the atmosphere.

The model produces a forecast, which is then compared to actual weather observations to determine its accuracy. Some models are designed to provide short-term forecasts, while others are better suited for long-term predictions. Some models are better at predicting certain types of weather events, such as hurricanes or thunderstorms. One of the most widely used NWP models is the Global Forecast System (GFS), which is run by the National Oceanic and Atmospheric Administration (NOAA). The model produces a forecast every six hours for up to 16 days in advance.In addition to these global models.

$$\frac{\Delta A}{\Delta T} = F(A),$$

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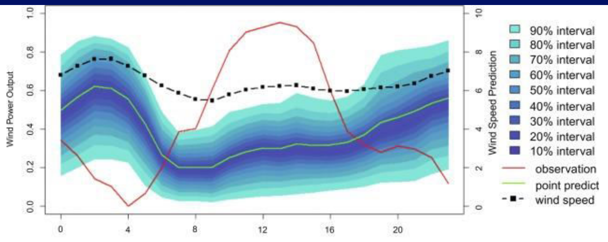
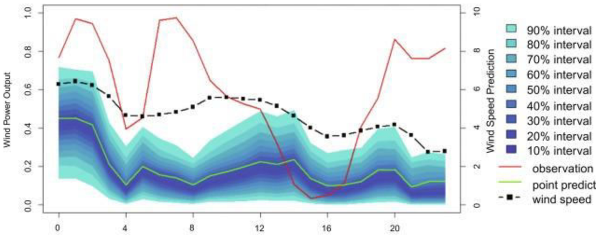


(A)

Wind Farm #5 2013/03/07 RMSE = 0.4030 QS = 0.1330



(B)

Wind Farm #10 2012/12/13 RMSE = 0.4852 QS = 0.1761

Numerical Weather Prediction has two categories

Global Models:

Global models, also known as global numerical weather prediction (NWP) models, play a significant role in weather forecasting by simulating and predicting weather patterns worldwide. These models provide forecasts on a global scale and are essential tools for meteorologists and forecasting agencies. Let's delve into the characteristics, components, and applications of global models in weather forecasting.

One of the most widely used NWP models is the Global Forecast System (GFS), which is run by the National Oceanic and Atmospheric Administration (NOAA). The GFS model uses a grid system to divide the atmosphere into small cells, each of which is simulated using mathematical equations. The model produces a forecast every six hours for up to 16 days in advance. Another popular NWP model is the European Centre for Medium-Range Weather Forecasts (ECMWF) model. The ECMWF model uses a similar grid system to the GFS model but uses more advanced algorithms to simulate atmospheric behavior

Characteristics of Global Models:

Large-Scale Coverage: Global models cover the entire globe, allowing for the prediction of weather phenomena across continents, oceans, and different climate regions.

Grid Resolution: Global models operate on a grid system, dividing the Earth's surface into numerous grid cells. In recent years, advancements in computational power have allowed for higher resolution global models that capture smaller-scale features with greater accuracy.

Forecast Timeframe: Global models are designed to provide forecasts for varying timeframes, from short-term forecasts extending up to a few weeks into the future. Short-term forecasts (e.g., 0-7 days) are typically more accurate, while medium-range forecasts (e.g., 7-14 days) offer a broader outlook.

Regional Models:

Regional Numerical Weather Prediction (NWP) models are a subset of NWP models that focus on providing localized weather forecasts for specific regions. These models use higher resolution grids and incorporate more detailed information about local weather patterns, such as topography, land use, and sea surface temperatures. Regional NWP models are particularly useful for predicting weather events that are influenced by local factors, such as sea breezes, mountainous terrain, or urban heat islands.

One example of a regional NWP model is the North American Mesoscale (NAM) model, which is run by the National Centers for Environmental Prediction (NCEP). The NAM model uses a grid system with a resolution of 12 kilometers and provides forecasts for up to 84 hours in advance. This model is used by meteorologists to predict severe weather events such as thunderstorms, tornadoes, and winter storms in the United States. Another example is the Canadian Regional Deterministic Prediction System (RDPS), which is run by Environment and Climate Change Canada.

Methodology :

In this paper, the system predicts the future weather conditions based on current weather data.

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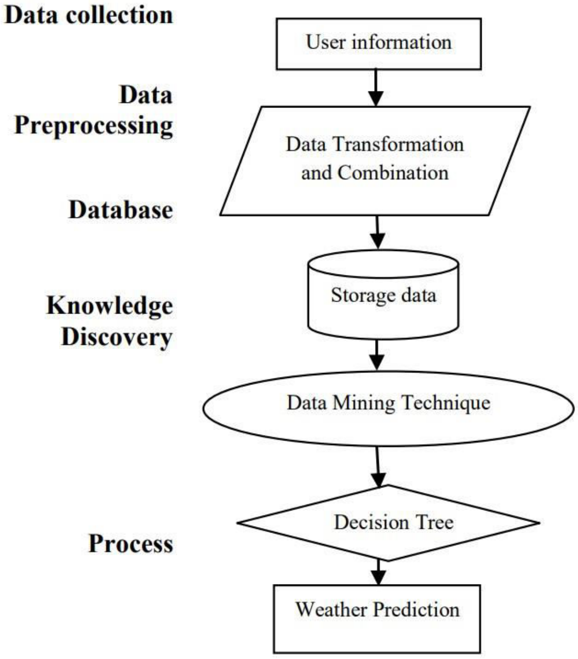


Data Mining Technique

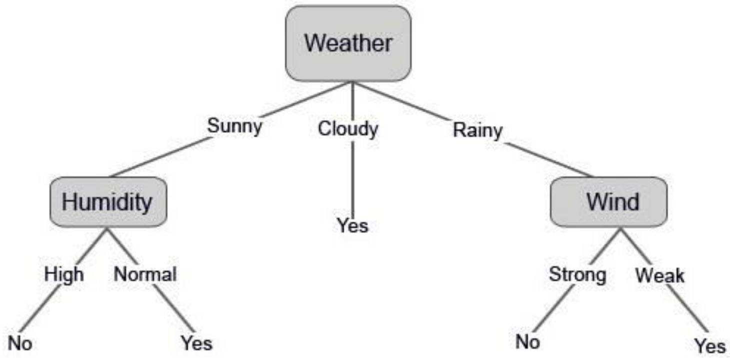
Data mining techniques are increasingly being used in weather forecasting to improve the accuracy and reliability of predictions. These techniques involve analyzing large datasets to identify patterns and relationships that can be used to make more accurate forecasts.

One example of a data mining technique used in weather forecasting is machine learning. Machine learning algorithms can be trained on historical weather data to identify patterns and relationships between different weather variables. These algorithms can then be used to make predictions about future weather conditions based on current data. Another data mining technique used in weather forecasting is clustering analysis. Clustering analysis involves grouping similar weather patterns together based on their characteristics, such as temperature, humidity, and wind speed.

Data mining techniques can also be used to improve the accuracy of long-term climate predictions. Despite the benefits of data mining techniques in weather forecasting, there are also some limitations to their use. One challenge is the need for high-quality data that is accurate and up-to-date. In addition, data mining techniques can be computationally intensive, requiring powerful computers and specialized software to analyze large datasets. Despite these challenges, data mining techniques are becoming increasingly important in weather forecasting and climate prediction. As technology continues to improve, these techniques will become even more powerful, helping us to better understand and respond to changes in our planet's climate.

Decision Tree :

The decision Tree generated from training data is helpful in making prediction. Construction of the decision tree is done by selecting the best possible attribute that will be able to split set of samples in most effective manner.



Persistence Forecasting:

Persistence forecasting is a technique that involves predicting future weather conditions based on the assumption that current weather patterns will continue unchanged. This method is based on the idea that the atmosphere tends to remain in a state of equilibrium, and that short-term weather patterns are often consistent over time. For example, if the current weather conditions are sunny and warm, a persistence forecast would predict that the weather will remain sunny and warm for the next few days. Similarly, if the current weather conditions are rainy and cool, a persistence forecast would predict that the weather will remain rainy and cool for the next few days.

Persistence forecasting is a simple and straightforward method of weather forecasting that requires minimal data and resources. It is often used as a baseline for other forecasting methods, as it provides a starting point for predicting future weather conditions. Persistence forecasting also does not take into account the long-term trends or variability of the atmosphere.

Use of Biometer:

Biometers are instruments that measure biological phenomena and can be used to provide valuable information about how weather conditions are affecting the natural world. This information can then be used to make predictions about future weather patterns. One of the main ways biometers are used in weather forecasting is to measure the growth and development of crops. By monitoring how crops are responding to weather conditions such as temperature, precipitation, and sunlight, meteorologists and weather forecasters can make predictions about agricultural productivity.

Climatology Forecasting :

Climatology is the study of long-term weather patterns and trends, and it plays an important role in weather forecasting. By analyzing historical weather data and trends, climatologists can make predictions about future weather patterns and help meteorologists and weather forecasters provide more accurate and reliable forecasts.

One of the main ways climatology is used in weather forecasting is through the use of climate models. These models simulate the Earth's climate system and can be used to make predictions about future weather patterns based on various scenarios and inputs.

Another way climatology is used in weather forecasting is through the analysis of long-term weather trends. By studying historical weather data, climatologists can identify patterns and trends in weather conditions such as temperature, precipitation, and extreme weather events. This information can be used to make predictions about future weather patterns and to identify areas that may be particularly vulnerable to certain types of extreme weather events.

Nowcasting :

Nowcasting is a type of weather forecasting that focuses on predicting short-term weather conditions, typically up to six hours in advance. Unlike traditional weather forecasting, which relies on computer models and historical data to make predictions about future weather patterns, nowcasting uses real-time data and observations to provide up-to-the-minute information about current weather conditions.

One of the main ways nowcasting is used in weather forecasting is through the use of radar and satellite imagery. By analyzing these images, meteorologists can track the movement of weather systems and identify areas of precipitation, such as rain, snow, and hail. These devices measure a range of weather variables, including temperature, humidity, wind speed, and precipitation. By collecting real-time data from these sensors, meteorologists can make short-term predictions about how weather conditions are likely to change over the next few hours. Nowcasting is particularly useful in situations where sudden changes in weather conditions can have a significant impact on people's lives and livelihoods.

Analogue Forecasting:

Analogue forecasting is a type of weather forecasting that relies on historical weather patterns to make predictions about future weather conditions. Analogue forecasting is based on the idea that weather patterns tend to repeat themselves over time.

One of the main advantages of analogue forecasting is that it can be used to make predictions even when there is limited data available. This is particularly useful in situations where weather monitoring equipment is not available or when data is missing due to technical problems or other issues.

Ensemble forecasting:

Ensemble forecasting is based on the idea that there is always some degree of uncertainty in weather forecasting. Even small variations in initial conditions or parameters can lead to significantly different outcomes. By running multiple simulations, meteorologists can account for this uncertainty and get a better sense of the range of possible outcomes.

To generate an ensemble forecast, meteorologists use computer models that simulate the behavior of the atmosphere and other components of the Earth's system. These models take into account a wide range of factors, including temperature, humidity, wind speed and direction, atmospheric pressure, and more.

In an ensemble forecast, each simulation is run with slightly different initial conditions or parameters. For example, one simulation might use a slightly higher or lower starting temperature than another simulation. By making these small variations, meteorologists can create a range of possible outcomes that reflects the inherent uncertainty in the weather system.

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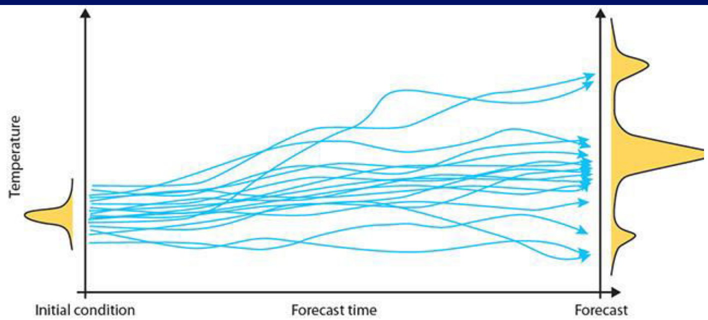
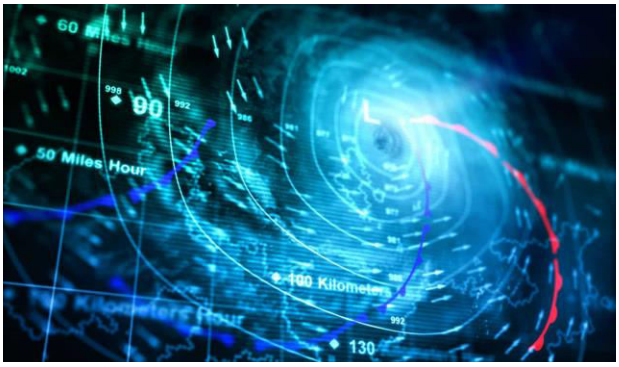


Classification based on models:

Artificial Intelligence for Weather Forecasting:

The improvement of artificial intelligence has inspired the growth self-learning models. These model are more effective compared to statistical models. AI models deals with nonlinear data effectively and produce better forecasting performance. These models are further divided into machine learning predictors and deep learning predictors. Artificial intelligence (AI) is increasingly being used in weather forecasting to improve the accuracy and reliability of predictions. One way that AI is being used in weather forecasting is through machine learning. Machine learning algorithms can be trained on historical weather data to identify correlations between different variables and make predictions about future weather conditions. Another way that AI is being used in weather forecasting is through predictive analytics. Predictive analytics algorithms can analyze real-time data from various sources to identify patterns and trends that may indicate the likelihood of certain weather conditions.



Machine learning predictors

Machine learning predictors For handling nonlinear datasets machine learning and deep learning are better models. SVM, ANN, ELM and Random Forests are some of the popular machine learning predictors. These predictors can also be used weather forecasting. This section provides the various learning techniques of machine learning. They include ML models, ANN based models and SVM based models.

ANN based models

ANN based models Neural Networks are supervised and predictive. They are one of the most popular techniques for weather prediction because they can obtain relationships of past weather trends and future weather conditions. An Artificial Neural Network comprises a network of neurons known as nodes, which are connected to each other. Neural network comprises of input layer, hidden layer and output layer. The node in the input layer transforms the given input and transfers it to the next node. Each node evaluates the value it obtains and then transforms the results according to the activation function.

SVM based models

SVM is defined by hyper plane that has minimum distance to the training data of samples. An optimal hyper plane has the maximum margin of training data. Using the kernel trick SVM can find nonlinear solutions and they also work well with high dimensional data. Kernels are mathematical functions that converts inputs to the desired format. The various functions solved by SVM algorithms are linear, nonlinear, polynomial, and sigmoid.

Deep Learning Predictors

Deep Learning Predictors Deep learning is section of machine learning algorithm, where it uses neural approach to gain intelligence and from huge datasets, and it make use of supervised or unsupervised learning in deep architectures to learn hierarchical representations. Deep learning has been successfully implemented in many areas such as speech recognition, time series and genomics

Conclusion:

This paper works with mix algorithm to predict weather condition. The system can be filled in as training tool for Meteorology Students. This methodology can decide the non-linear relationship that exists between the historical data (temperature, wind speed, humidity, and so forth.,) provided to the system during the training phase and on that premise, make a prediction of what the weather would be in future. The Future work of this project is to incorporate more attribute of weather condition to predict and to work with other classification algorithm to become more accurate in prediction. Weather forecasting is a complex and challenging science that depends on the efficient interplay of weather observation, data analysis by meteorologists and computers, and rapid communication systems. Meteorologists have achieved a very respectable level of skill for shortrange weather forecasting. Further improvement is expected with denser surface and upper air observational networks, more precise numerical models of the atmosphere, larger and faster computers and more are to be realized. As a whole, the sole purpose of this study is to learn about the different techniques used in prediction of weather forecast. This study provides insight about weather forecast and different methods involved to predict them. It is summarized and concluded that hybrid techniques have optimized results compared to other techniques. Hence, choosing the optimized technique and applying them for yielding better performance is an important task and a challenging risk.

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