**SMART REAL TIME WEATHER FORECASTING SYSTEM**

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**DECLARATION**

I, **Geetesh Muralitharan,** hereby declare that the Product Design Report entitled “**SMART REAL-TIME WEATHER FORECASTING SYSTEM**” done by me under the guidance of **Ms. Aishwarya D** , is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Computer Science and Engineering .

**ABSTRACT**

Weather forecasting is the attempt by meteorologists to predict the weather conditions at some future time and the weather conditions that may be expected. The climatic condition parameters are based on the temperature, wind, humidity, rainfall and size of data set. Here, the parameters temperature and Humidity only are considered for experimental analysis.

A weather forecast requires collection, analysis, and interpretation of data from a variety of sources that are :

**1. Surface observation**

**2. Upper-air observation**

**3. Radar data**

**4. Satellite imagery**

After these steps meteorologists identify the patterns and trends in the atmosphere which further leads to creation of computer models that simulate the atmosphere and predict how it changes the future.

Weather forecasts are issued for variety of time periods, long range ,medium range, long range. Short range forecasts are generally the most accurate while long range forecasts are uncertain. So in this project we are bringing in the rulers of this futuristic world, THE AI (**ARTIFICIAL INTELLIGENCE**) which makes the entire process easier giving an accurate solution.

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* **INTRODUCTION**

**1.1. WHAT IS WEATHER FORECASTING?**

Weather forecasting is the application of science and technology to predict the conditions of the atmosphere for a given location and time. It even plays a crucial role in many aspects of modern society. Weather forecasts are made by collecting quantitative data about the current state of the atmosphere, land, and ocean and using [meteorology](https://en.wikipedia.org/wiki/Meteorology) to project how the atmosphere will change at a given place.Here is a vast variety of end uses for weather forecasts. [Weather warnings](https://en.wikipedia.org/wiki/Weather_warning) are important because they are used to protect lives and property. Forecasts based on temperature and [precipitation](https://en.wikipedia.org/wiki/Precipitation_(meteorology)) are important to agriculture, and therefore to traders within commodity markets. Temperature forecasts are used by utility companies to estimate demand over coming days.

On an everyday basis, many people use weather forecasts to determine what to wear on a given day. Since outdoor activities are severely curtailed by heavy rain, snow and [wind chill](https://en.wikipedia.org/wiki/Wind_chill), forecasts can be used to plan activities around these events, and to plan ahead and survive them.

**1.2. USES OF WEATHER FORECASTING**

* **Surface observations:** These are measurements of temperature, humidity, wind speed and direction, atmospheric pressure, and other weather conditions taken at ground level from weather stations around the world.
* **Upper-air observations:** These are measurements of temperature, humidity, wind speed and direction, and atmospheric pressure taken from balloons, aircraft, and satellites.
* **Radar data:** Radar can be used to detect and track clouds and precipitation.
* **Satellite imagery:** Satellite imagery can be used to track cloud cover, sea and surface temperatures, and other weather features.

Once the data has been collected, it is analyzed by meteorologists to identify patterns and trends in the atmosphere. Meteorologists then use this information to create computer models that simulate the atmosphere and predict how it will change in the future.

Even though Weather forecasting helps individuals plan their daily activities, businesses make informed decisions, and governments prepare for and respond to extreme weather events. Accurate weather forecasts can save lives and property by providing warnings of severe storms, floods, and other hazards.

**IMPORTANCE OF WEATHER FORECASTING**

There are various uses of weather forecasting in day-to-day life

* Seasons and nature play a major role in agriculture and farming. When it comes to the farming of various fruits, vegetables, and pulses, temperature is extremely important.
* It aids food grain transportation and storage.
* It aids in the handling of cultural operations such as harrowing, hoeing, etc.
* It aids in the implementation of livestock protection initiatives.
* Weather Forecasting is crucial since it helps to determine future climate changes. With the use of latitude, we can determine the probability of snow and hail reaching the surface. Climatology is the scientific study of climates, which in simple words mean weather conditions over a period.
* **EXISTING SYSTEM FOR THE WEATHER FORECAST**

The existing system for weather forecasting is a complex network of data collection, analysis, and modeling that involves a variety of organizations and technologies.

**2.1. Primary data collection:**

The primary data collection for weather forecasting is done through a network of weather stations located around the world. These stations measure a variety of atmospheric conditions, including temperature, humidity, wind speed and direction, atmospheric pressure, and precipitation. The data from these stations is transmitted to central repositories where it is analyzed by meteorologists.

**2.2. Secondary Data collection:**

In addition to surface observations, meteorologists also use data from upper-air observations, radar, and satellites. Upper-air observations are taken by balloons and aircraft, and they provide data on temperature, humidity, wind speed and direction, and atmospheric pressure at different altitudes. Radar data can be used to detect and track clouds and precipitation, while satellite imagery can be used to track cloud cover, sea and surface temperatures, and other weather features.

**2.3. Tools needed for forecasting the weather**

There are a number of tools in the meteorologist's arsenal to help predict the weather. Below are a few:

**Weather radar**

Weather radar is a tool used to measure precipitation, incoming storms, and other severe weather.

**Weather balloons**

Weather balloons are used to measure temperature, wind speed and direction, and air pressure in the layers of the troposphere.

**Barometer**

A barometer is a forecasting tool used to measure atmospheric pressure in a certain environment.

**Thermometers**

Thermometers measure the temperature in a given location.

**Satellite and weather data**

Satellite and weather data observe cloud patterns around the globe. There are three types of satellites that meteorologists use:

* Polar-orbiting satellites
* Geostationary satellites
* Deep space satellites

**Weather stations**

Weather stations observe temperature, humidity, barometric pressure, wind speed and direction, and rainfall.

**IoT sensors**

IoT-enabled technology measures weather factors like temperature, moisture, and pressure. DHT11 sensor is a low cost digital sensor that measures temperature and humidity whereas DHT stands for Digital Humidity and Temperature. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air. It outputs a digital signal on the data pin. The sensor is factory calibrated and can be easily interfaced with other microcontrollers. This sensor is commonly used in applications such as :

* Weather monitoring
* Home automation
* Industrial control systems

**Weather forecasting models**

Data sets collected need to be inputted into a weather forecasting model that can understand how various inputs can affect the outcome of different weather events.

**2.4. Methods which are used to find the Weather forecasting**

* **Synoptic Method:**  A systematic study of recent weather forecasts from a wide area is used in this method of weather forecasting. Present weather conditions are linked to comparable scenarios in the past, and predictions are based on the premise that the current scenario would behave similarly to the analogous situation in the past.
* **Statistical Method:** Regression equations or other advanced relationships are formed between various weather elements and the subsequent climate in this method of weather forecasting. Predictions or weather criteria are usually chosen based on a potential physical interaction with the predictions.
* **Numerical Weather Prediction Techniques:** Numerical weather prediction definition states that it forecasts weather using statistical models of the atmosphere and oceans dependent on current weather conditions. The action of the atmosphere is expressed in this system by a series of equations based on physical laws governing airflow, air pressure, and other data. The method has been shown to be optimal for medium-term forecasts.

**OPPORTUNITY FOR THE FUTURE IMPROVEMENT**

Opportunities exist for increasing forecast skill at all time ranges.  However, realizing these opportunities will require further research, close international cooperation and coordination, improved observations of the atmosphere, ocean, and land surface, and the incorporation of these observations into numerical models. Also, benefit will be derived from higher spatial resolution of numerical models; increasingly powerful supercomputers; wider use and improvement of model ensembles; the development of data mining and visualization methods that enable forecasters to make better use of model guidance; and collaborative forecast development activities among operational forecasters and researchers.

 For example, research conducted by social scientists across multiple disciplines has found that delivering weather warnings across multiple media increases the likelihood that people will get and act upon this information. Collaborative research with social scientists will also enable forecasters to codify best practices in forecasting philosophy, communication, and training amidst rapid technological change. An increase in the presence and use of social media is contributing to additional avenues for providing weather information and collecting real-time observations.

**2.5. How are forecast used?**

* Government officials use hurricane forecasts to inform evacuation decisions, declare states of emergencies, and spur the public to action in advance of the expected hazards.
* Power companies use forecasts of high-impact weather events such as severe thunderstorms, hurricanes, extreme heat and wildfires, and freezing rain and blizzards to deploy equipment and personnel to help restore power after the associated threats have subsided.
* Departments of Public Works or Transportation use forecasts to order supplies such as salt and de-icer, prepare equipment, and coordinate staffing to prepare for and respond to winter storms.
* Water management and treatment agencies use short- to medium-range forecasts to determine if water should be released from a reservoir or treated and released from a water-treatment facility in advance of anticipated rainfall.

**2.6. Benefits of accurate weather forecasting**

There are a number of benefits to providing accurate weather forecasting. They include the following:

**Broadcasters can better inform their viewers**

By incorporating accurate forecasting into their [news production](https://www.ibm.com/weather/industries/broadcast-media/news-video-production), broadcasters will keep viewers tuned in which increases ratings, advertiser demand and revenue. Broadcasting companies can also confidently advertise themselves as an accurate source for weather forecasts which establishes trust and credibility.

**Advertisers can better target their audiences**

With solutions like IBM Watson Advertising’s [weather targeting](https://www.ibm.com/products/weather-targeting), which leverages accurate weather data, advertisers can target consumers based on the upcoming weather conditions in their area. For example, if it suddenly gets colder in Florida, advertisers can present messaging that encourages users to buy a hot coffee. Weather targeting is also sophisticated enough to determine that weather must be combined with geo-location. For example: 60 degrees in Miami may have locals unpacking their winter gear, while 60 degrees in Massachusetts will likely have Bostonians enjoying the outdoors in short sleeves.

**Airplanes can monitor turbulent weather**

Having an accurate reading of weather conditions is essential to airplane pilots. There needs to be an awareness of any upcoming turbulent weather conditions in order to plan accordingly and keep passengers safe.

**Utility companies can plan for outages and repairs**

Having accurate weather forecasts allows utilities to properly schedule their team for anticipated outages and repairs. By utilizing accurate [weather technology](https://www.ibm.com/weather/industries/broadcast-media/innovation-weather-forecasting-technology-broadcast), utility companies can better prepare the grid and more effectively keep the lights on.

* **LIMITATIONS OF THE WEATHER FORECAST**

There are some inherent limitations to the existing systems for weather forecasting:

**1. Inherent Uncertainty of the Atmosphere:** The atmosphere is a complex and chaotic system, governed by non-linear interactions among various components. This inherent uncertainty limits the predictability of weather events, particularly for localized phenomena like thunderstorms or tornadoes.

**2. Data Limitations:** The accuracy of weather forecasts is heavily dependent on the quality and quantity of observational data.While satellite and radar technologies have improved data collection, there are still gaps in coverage, particularly over remote areas, oceans, and developing regions.

**3. Model Resolution and Complexity:** Numerical weather prediction (NWP) models are simplified representations of the atmosphere, and their accuracy is constrained by computational limitations.While model resolution has improved over time, there are still trade-offs between spatial detail and computational cost.

**4. Regional and Local Variations:** Weather patterns can vary significantly across different regions due to factors like topography, land-sea interactions, and local climate conditions. Even in some areas, NWP models may not fully capture these regional and local variations, leading to reduced accuracy in certain areas.

**5. Forecast Communication and Interpretation:** Translating complex model outputs into understandable and actionable weather forecasts requires expertise and effective communication skills.

Despite these limitations, weather forecasting has made remarkable progress, and the accuracy of forecasts has improved significantly over time. Meanwhile, in the future, the research and technological advancements are addressing these limitations, leading to more reliable and detailed weather forecasts.One of the primary factors that make weather forecasting difficult is the chaotic nature of the atmosphere. The atmosphere is a complex system that is sensitive to even the smallest changes in its initial conditions. This sensitivity is known as the butterfly effect, where a small change in one part of the system can have significant effects on other parts of the system. In weather forecasting, this means that small errors in our measurements or initial conditions can lead to large discrepancies in our predictions.

Another factor that makes weather forecasting difficult is our limited ability to observe the atmosphere. While we have many tools at our disposal, such as satellites, radars, and weather balloons, there are still many areas of the atmosphere that we cannot observe directly. This lack of data can lead to errors in our initial conditions, which can then propagate through our models and lead to inaccurate forecasts.

**Disadvantages of Weather forecasting**

The disadvantages pertaining to forecasting include the following:

* **Forecasts are Never Completely Accurate** - Forecasts are never 100% and it is almost impossible to predict the future with certainty. Even if you have a great process in place and forecasting experts on your payroll, your forecasts will never be spot on. Some products and markets will have a high level of volatility, especially during times of crisis. The coronavirus has definitely enhanced and increased this volatility within the market - which is why understanding what factors influence your demand can potentially aid with developing forecasts during this time. Having said that, the main drawback of forecasts are that they are almost always wrong - which leads to excess or shortage of inventory.
* **It can be Time-Consuming and Resource-Intensive** - Forecasting pertains to data gathering, data organizing, and coordination. Companies will employ a team of demand planners who are responsible for coming up with the forecast. In order to adequately conduct this function, demand planners will need a substantial amount of input from sales and marketing teams. It is also not uncommon for process to be manual and labor-intensive, which will ultimately take up a lot of time. If you have the correct technology in the right place, it is much less of an issue.
* **Could be Costly** - Forecasting can be extremely costly - especially if it is done right. If you want adequate and close-to-accurate forecast, you have to spend the money, time, and resources to do so. Hiring a team of demand planners is a significant investment and adds to the cost of utilizing quality tools. While it is costly, you should easily see a return on this investment over time and your forecast should be much more accurate, thus saving you money and paying for itself in the long run.
* **PROPOSED SYSTEM FOR WEATHER FORECAST**

There are some proposed systems aim to overcome the inherent complexity of the atmosphere and improve the representation of weather patterns.

* **Ensemble Forecasting:** Ensemble forecasting involves running multiple numerical weather prediction (NWP) models with slightly different initial conditions or model parameters. Each model produces a slightly different forecast, and the forecast results provides a more comprehensive picture of potential weather scenarios.
* **Machine Learning and Artificial Intelligence:** Machine learning (ML) and artificial intelligence (AI) plays an important role in weather forecasting. For example, AccuWeather uses these features and these techniques are being applied to weather forecasting to extract patterns and relationships from large datasets of observational and model data. Mainly, ML algorithms can identify subtle patterns in historical data and use those patterns to make more accurate predictions about future weather events.
* **High-Resolution Modelling:** High-resolution models can capture smaller-scale weather phenomena, such as thunderstorms or tornadoes, which are often difficult to predict with traditional models. This allows for more detailed representation of atmospheric features and improved prediction of localized weather events.
* **Data Fusion and Assimilation:** Advanced data assimilation techniques are being developed to integrate diverse observational data from satellites, radars, weather stations, and other sources. And the data fusion combines observational data with model predictions to create a more accurate representation of the current state of the atmosphere.

**Cloud and precipitation prediction**

If the density of water vapor is added to standard dynamic variables, it becomes possible to predict clouds and precipitation in addition to the air motion. When a parcel of air containing a fixed quantity of water vapor ascends, it expands adiabatically and cools until it becomes saturated. Continued ascent produces clouds and precipitation. The most successful predictions made by this method are obtained in regions of strong rising motion, whether induced by forced orographic ascent or by horizontal convergence in well-developed cyclones. The physics and mechanics of the convective cloud-formation process make the prediction of convective cloud and showery precipitation more difficult.

These proposed systems, in conjunction with ongoing research and technological advancements, hold promise for enhancing the accuracy, reliability, and usefulness of weather forecasts. Therefore, Weather forecasting can provide better guidance for decision-making and preparedness in various sectors of society.

**ANALYSIS OF WEATHER DATA**

Forecasting the weather begins by continuously observing the state of the atmosphere, the ocean, and land surface.  The World Meteorological Organization provides the framework for an evolving worldwide suite of observing systems, such as satellites, radars, and surface weather observations that aid in monitoring these conditions. Although major research challenges remain, scientists have made considerable progress in developing mathematical techniques to integrate these observations into snapshots of the land surface and atmospheric state at any given time.  These analyses serve as the foundation for weather prediction on scales from individual clouds to regional severe weather events and global patterns. Analyses of current and past weather support many diverse environmental applications, including fundamental scientific investigations of the climate system.

Weather forecasting begins with an analysis of the current state of the atmosphere, ocean, and land surface. Reliable observations drawn from many platforms, including satellites, radar, weather balloons, surface stations, and aircraft (both crewed and uncrewed) are crucial for generating accurate analyses. Because forecast quality is partially reliant on the quality of the underlying analysis, scientists continue to develop techniques to integrate observations into four-dimensional model representations of the Earth system. In addition to their vital role in weather forecasting, these analyses support scientific investigations designed to help develop improved weather prediction tools and techniques.

**IMPLEMENTATION OF AI IN WEATHER FORECAST**

Both weather broadcasters and viewers have greatly benefited from the integration of AI technologies, revolutionizing how predictions are made and communicated. Here are some of the most common applications of AI within the field:

**Weather Prediction**

Using AI for weather prediction is not a new innovation and has been in use since the 1970s. The weather models that broadcasters rely on to make accurate forecasts consist of complex algorithms run on supercomputers. Machine-learning techniques enhance these models by making them more applicable and precise.

**Content Triggers**

Besides traditional TV and radio broadcasts, many broadcasters today offer dedicated smartphone apps that provide up-to-the-minute weather information to viewers. One way [AI helps broadcasters](https://www.ibm.com/weather/industries/broadcast-media/will-ai-replace-television-meteorologist) personalize the app experience is by enabling content triggers. A content trigger is a set of weather factors that automatically trigger an action in the app, such as sending the user a notification. For example, a broadcaster could set a trigger to send viewers safety [graphics](https://www.ibm.com/weather/industries/broadcast-media/weather-graphics-ultimate-guide) when temperatures in their area exceed a certain threshold for a certain amount of time in a day. These content triggers ensure that individuals receive timely and relevant information, enhancing their awareness and preparedness in weather-related situations.

**Severe weather & weather alerts**

On the forecasting side, by analyzing real-time data, AI can rapidly identify potential hazards such as lightning strikes, high winds or flash flooding. Then, in-app AI plays a crucial role in sending viewers automated [severe weather alerts](https://www.ibm.com/weather/industries/broadcast-media/overview-severe-weather-alerts-warnings) to keep them safe. These timely notifications enable individuals to take immediate action, seek shelter, or evacuate if necessary, minimizing the risks associated with [severe weather](https://www.ibm.com/weather/industries/broadcast-media/severe-weather) events.

**Lifestyle content**

AI augments TV weather segments with lifestyle-related content, making weather updates more engaging and habitual. This includes providing broadcasters with health, wellness and scientific information that complements weather reports, such as air quality indexes, pollen forecasts and UV index levels. By integrating this additional context, AI enhances the user experience, enabling individuals to make more informed decisions about outdoor activities, health precautions and overall well-being based on the weather conditions.

**Traffic reports**

AI can monitor [traffic flows and drive times](https://www.ibm.com/products/max-traffic) to generate content that helps broadcasters inform viewers about traffic conditions and possible delays. This insight improves the accuracy and timeliness of traffic reports, allowing individuals to plan their commutes more effectively and make informed decisions about alternative routes or modes of transportation to avoid congestion.

**BENEFITS OF WEATHER FORECAST USING AI**

Using AI in weather forecasting offers several significant benefits to the field.

**Faster Weather Predictions**

AI algorithms enable remarkable speed in processing vast amounts of data, resulting in faster and more immediate weather predictions. The ability to analyze extensive data sets in real time allows meteorologists and forecasters to provide timely and up-to-date information to individuals, businesses and governments. This speed is particularly crucial during rapidly evolving weather situations, such as severe storms or approaching hurricanes, where quick decisions and actions are necessary.

**More Accurate Predictions**

Moreover, machine learning in particular enhances the [accuracy of weather forecasts](https://www.ibm.com/weather/industries/broadcast-media/complete-guide-accurate-weather-forcasting). AI algorithms learn from historical and real-time data, identifying intricate patterns and correlations that might go unnoticed through traditional analysis methods. Sophisticated weather models can also account for complex weather conditions that are difficult to simulate through other means. This leads to more precise predictions, enabling individuals and organizations to make better-informed decisions based on the most accurate available information.

**Enhanced Efficiency**

Additionally, AI-driven automation processes bring enhanced efficiency to weather forecasting operations. By automating data processing and other tasks, AI enables meteorologists to focus more on the interpretation, analysis and communication of weather information. This shift allows experts to delve deeper into the implications and impacts of weather conditions, providing valuable insights and actionable recommendations to various stakeholders. The streamlined operations driven by AI also contribute to improved resource allocation and cost-effectiveness within weather-forecasting departments and organizations.

* **ARCHITECTURAL DIAGRAM**



* **CONCLUSION**

As weather forecasting continues to evolve, it will become increasingly integrated into various aspects of society, providing more useful and valuable information for specific user groups and decision-makers. The ability to anticipate and prepare for weather events will become even more critical in a changing climate, where extreme weather events are likely to become more frequent and intense.

In conclusion, weather forecasting is a dynamic and evolving field that plays a vital role in protecting lives and property, supporting economic activities, and informing decision-making in various sectors. With ongoing advancements in science and technology, weather forecasting will continue to improve and provide increasingly valuable insights into the complexities of our atmosphere.

Weather forecasts are increasingly accurate and useful, and their benefits extend widely across the economy. While much has been accomplished in improving weather forecasts, there remains much room for improvement. The forecasting community is working closely with multiple stakeholders to ensure that forecasts and warnings meet their specific needs. Simultaneously, they are developing new technologies and observational networks that can enhance forecaster skill and the value of their services to their users.

The two different types of forecasting models, one of them based on finite differences, the other one based on the spectral method, are currently competing as to which one of them yields more accurate forecasts for a given computational cost. But at the end of the day, each model has its strengths and weaknesses; so using both models side by side will probably give the best results.

In the future, weather forecasts will be even more accurate and more detailed than forecasts nowadays. And who knows, maybe one day mathematicians will find a way to overcome the two weeks forecasting limit, so that long-range forecasts can produced.

* **REFERENCE**

**Wikipedia -** [**https://en.wikipedia.org/wiki/Weather\_forecasting**](https://en.wikipedia.org/wiki/Weather_forecasting)

**IBM-https://www.ibm.com/weather/industries/broadcast-media/complete-guide-accurate-weather-forcasting**

**Britannica -** [**https://www.britannica.com/science/weather-forecasting**](https://www.britannica.com/science/weather-forecasting)

**Access Science -** [**https://www.accessscience.com/content/article/a742600**](https://www.accessscience.com/content/article/a742600)

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