



Weather Data Analysis and Visualization Dashboard using Data Science Techniques

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Abstract- The rapid growth of environmental data has significantly increased the need for efficient analytical frameworks capable of transforming raw meteorological information into meaningful insights. Weather data, which includes parameters such as temperature, humidity, rainfall, and wind speed, is inherently complex, high-dimensional, and continuously evolving. Traditional weather monitoring systems primarily focus on data collection and basic reporting, often lacking advanced analytical and visualization capabilities required for comprehensive understanding. This research presents a data science-driven approach for analysing and visualizing weather data through an interactive dashboard system. The proposed study emphasizes the application of data preprocessing, statistical analysis, and visualization techniques to extract meaningful patterns and trends from historical and real-time weather datasets. By leveraging modern data science tools, the system enables users to interpret climatic variations effectively and supports informed decision-making. The research further investigates the role of visualization in simplifying complex datasets and enhancing user comprehension. Graphical representations such as line plots, bar charts, and heatmaps are utilized to highlight temporal and spatial variations in weather parameters. The findings suggest that integrating analytical techniques with interactive visualization significantly improves the accessibility and usability of weather data. Despite its advantages, the study acknowledges certain limitations, including data inconsistency, dependency on external APIs, and scalability concerns. However, the proposed framework demonstrates strong potential for future enhancement through the integration of predictive models and real-time analytics. Overall, this research highlights the importance of data science in advancing weather data analysis and promoting data-driven environmental awareness.

Keywords: Weather Data Analysis, Data Science, Data Visualization, Interactive Dashboard, Data Preprocessing, Exploratory Data Analysis, Climate Data, Real-time Data.

I. Introduction

In recent years, the rapid growth of data generation has transformed the way different fields operate, especially in areas like environmental science and meteorology. Weather data, collected through satellites, sensors, and meteorological stations, has become one of the most important sources of both real-time and historical environmental information. This data is widely used in areas such as agriculture planning, disaster management, aviation, and climate research. Despite its importance, weather data is often complex and difficult to interpret. It usually consists of large volumes of numerical values that are not easy to understand without proper tools. Most traditional weather systems mainly focus on data collection and basic forecasting, which often fail to reveal deeper patterns such as seasonal changes, trends, or variations over time.

Weather data plays a crucial role in many real-world applications, including agriculture planning, disaster management, aviation, transportation, environmental monitoring, and climate research. Farmers depend on weather information to plan irrigation and crop cultivation activities, while government agencies and



researchers use weather data for climate studies and natural disaster preparedness. Accurate interpretation of weather conditions is also important in sectors such as tourism, logistics, and urban planning. However, despite the availability of large volumes of weather data, extracting meaningful insights from this information remains a major challenge.

One of the key difficulties associated with weather data is its complexity. Weather datasets are usually high-dimensional, continuously changing, and generated at high speed from multiple sources. Raw meteorological data often contains inconsistencies, missing values, duplicate records, and unstructured formats, making it difficult to interpret directly. Traditional weather monitoring systems generally focus on data collection and basic forecasting, providing information in the form of raw numerical values or static reports. While these systems are useful for basic observations, they often fail to provide deeper analytical insights or highlight important trends and relationships hidden within the data. As a result, users may struggle to understand long-term climatic variations, seasonal trends, and correlations between different weather parameters.

Data science provides an effective and modern solution to these challenges. By applying techniques such as data preprocessing, exploratory data analysis, statistical analysis, and visualization, it becomes possible to transform raw weather data into meaningful and structured insights. Data preprocessing helps improve the quality of the dataset by handling missing values, removing inconsistencies, and standardizing data formats. Exploratory analysis enables the identification of patterns, trends, and relationships between variables, while visualization techniques help present complex information in a simple and understandable manner. Graphical representations such as line charts, bar graphs, scatter plots, and heatmaps allow users to interpret weather patterns more easily compared to raw numerical data.

Among all data science techniques, visualization plays a particularly important role because it simplifies large and complex datasets into intuitive graphical forms that can be easily understood by both technical and non-technical users. Instead of analyzing large tables of numerical values, users can quickly identify temperature fluctuations, rainfall distribution, seasonal variations, and humidity patterns through visual analytics. Interactive dashboards further enhance this experience by allowing users to dynamically filter and explore weather data based on parameters such as location, date range, and weather conditions.

The motivation behind this research arises from the gap between the availability of weather data and its practical usability. Although large amounts of meteorological data are readily accessible today through APIs and online platforms, there is still a lack of systems that provide efficient analysis and user-friendly visualization of this information. Existing weather systems are often limited, static, and non-interactive, making it difficult for users to explore the data in depth or derive meaningful conclusions from it. At the same time, there is a growing need for climate awareness and data-driven decision-making in modern society. Individuals and organizations increasingly require accurate and understandable weather insights to support planning, research, and environmental monitoring activities.



In practical scenarios, users such as farmers, researchers, policymakers, environmental analysts, and students do not simply require raw data; instead, they need clear, structured, and actionable insights that can support decision-making processes. This creates the need for systems that not only collect and analyze weather data but also present it in a meaningful and visually understandable form. Based on this requirement, the problem addressed in this research is the lack of effective systems for analyzing and visualizing weather data interactively. Most existing solutions either focus only on data collection or provide limited visualization capabilities without deeper analytical functionality. Consequently, important patterns such as seasonal temperature changes, rainfall variations, humidity trends, and environmental correlations often remain difficult to identify.

To address these challenges, this study proposes a data science-based approach for weather data analysis and visualization through an interactive dashboard system. The research aims to develop a framework that integrates data collection, preprocessing, statistical analysis, and visualization into a single platform. The primary objectives of the study are to understand the structure and characteristics of weather datasets, improve data quality through preprocessing techniques, perform exploratory and statistical analysis, and represent the results using effective visualization methods. Another important objective is to design a user-friendly interactive dashboard that allows users to explore and interpret weather data easily and efficiently. The scope of this research is limited to the analytical and visualization aspects of weather data using data science techniques. The study focuses on collecting weather data from APIs and datasets, preprocessing the data, performing analysis, and presenting the results through graphical representations and interactive dashboards. The system is intended to support descriptive and exploratory analysis rather than advanced predictive modeling. Therefore, machine learning-based forecasting and predictive weather analysis are not included within the scope of this research. However, the proposed framework provides a strong foundation for future enhancements involving predictive analytics, real-time monitoring, and intelligent weather forecasting systems.

Overall, this research highlights the importance of integrating data science techniques with visualization tools to improve the interpretation, accessibility, and usability of weather data. By transforming complex meteorological information into meaningful insights through interactive dashboards and graphical representations, the proposed system contributes toward better environmental awareness, improved analytical capabilities, and more effective data-driven decision-making.

II. Literature review



The analysis of weather data has gained significant attention in recent years due to the rapid increase in environmental data generated from sources such as satellites, sensors, and meteorological stations, making traditional data handling approaches insufficient for extracting meaningful insights from large and complex datasets. As a result, researchers have increasingly adopted data science techniques—including preprocessing, statistical analysis, machine learning, and visualization—to better understand weather patterns and trends. Smith (2020) focused on transforming raw weather data into meaningful visual representations using charts such as line graphs, bar charts, and heatmaps, demonstrating that visualization significantly improves interpretability, although the study was limited to static outputs without interactive features or real-time updates. Kumar (2021) explored the use of machine learning models, including regression, decision trees, and neural networks, to analyze relationships between weather parameters and improve prediction accuracy; however, the approach required high computational resources and technical expertise, and it primarily emphasized prediction rather than visualization or user interaction. Lee (2019) presented a real-time weather monitoring system that collected data from external APIs and displayed current weather conditions through a web interface, highlighting the importance of real-time data access, but offering only basic visualization with limited analytical depth. Sharma (2022) provided a comprehensive overview of data science applications in environmental monitoring, discussing processes such as data cleaning, preprocessing, exploratory analysis, and visualization, and emphasizing their role in extracting meaningful insights; however, the study remained conceptual and did not propose an integrated system combining these components into a unified platform. Overall, these studies indicate that while advancements have been made in individual areas such as visualization, machine learning, and real-time data collection, there is still a lack of integrated systems that combine analysis, interaction, and visualization effectively, which this research aims to address through the development of an interactive weather data analysis and visualization dashboard.

III. Proposed methodology

The proposed methodology for the Weather Data Analysis and Visualization Dashboard is designed as a structured data processing pipeline that transforms raw meteorological data into meaningful insights through systematic stages. The approach integrates data collection, preprocessing, analysis, and visualization into a unified workflow to ensure accuracy, usability, and effective interpretation of weather information.

The process begins with data acquisition, where weather data is collected from reliable sources such as public APIs and structured datasets. These sources provide key parameters including temperature, humidity, rainfall, and wind speed across different time intervals. Since the data originates from multiple sources, it may contain inconsistencies, missing values, and variations in format.

To address this, the next stage involves data preprocessing, which is critical for ensuring data quality. In this step, missing values are handled using appropriate techniques such as imputation or removal, duplicate records are eliminated, and inconsistencies are corrected. The data is then standardized through normalization



and transformation, and date-time fields are formatted properly to support time-series analysis. This stage ensures that the dataset is clean, structured, and ready for analysis.

Following preprocessing, the system performs data analysis using statistical and exploratory techniques. Measures such as mean, median, and standard deviation are calculated to understand the distribution of weather parameters. Trend analysis is conducted to identify seasonal patterns and variations over time, while correlation analysis is used to examine relationships between variables, such as the effect of humidity on temperature or rainfall. These techniques help convert raw numerical data into meaningful insights and patterns.

The next stage focuses on data visualization, where analytical results are presented using graphical representations. Various visualization techniques such as line charts, bar graphs, and heatmaps are used to highlight trends, comparisons, and intensity variations in weather parameters. These visualizations simplify complex data and make it easier for users to interpret patterns without requiring advanced technical knowledge.

Finally, all components are integrated into an interactive dashboard system, which serves as the user interface for the application. The dashboard allows users to select parameters such as location, date range, and weather attributes, and dynamically generates corresponding visualizations and analytical outputs. The system is implemented using Python-based frameworks such as Streamlit or Flask, ensuring ease of use, flexibility, and accessibility. Interactive features such as filtering and real-time updates enhance user engagement and improve the overall effectiveness of the system.

Overall, the proposed methodology follows a systematic and modular approach, where each stage contributes to transforming raw weather data into actionable insights. By combining data science techniques with interactive visualization, the methodology ensures improved data interpretation, better usability, and support for data-driven decision-making.

IV. Result and Discussion

The Weather Data Analysis and Visualization Dashboard was successfully designed, implemented, and tested using both historical and real-time weather datasets collected from publicly available APIs and structured data sources. The system demonstrated the effective integration of multiple stages, including data collection, preprocessing, analysis, and visualization, into a single unified framework. The implementation process confirmed that the proposed approach is capable of transforming large volumes of raw meteorological data into meaningful, structured, and visually interpretable information. The dashboard handled important weather parameters such as temperature, humidity, rainfall, and wind speed efficiently, allowing users to analyze climatic conditions in a simplified and interactive manner.



One of the most important stages in the system was the preprocessing of weather data. Since the data collected originated from multiple sources, several inconsistencies were identified during the initial phase, including missing values, duplicate entries, inconsistent formatting, and irregular timestamps. These issues were addressed through preprocessing techniques such as data cleaning, removal of duplicate records, normalization, and formatting of date and time fields. Missing values were either removed or replaced using suitable methods to ensure continuity in the dataset. This preprocessing stage significantly improved the overall quality, consistency, and reliability of the data. As a result, the analytical outputs generated by the system were more accurate and dependable. The study confirmed that proper preprocessing is essential in any data science application because inaccurate or incomplete datasets can lead to misleading interpretations and unreliable results.

After preprocessing, the system performed statistical and exploratory analysis on the weather data to identify important trends, variations, and relationships among different parameters. Statistical measures such as mean, median, maximum, minimum, and standard deviation were calculated to understand the distribution and variability of weather conditions across different time periods. The analysis revealed clear seasonal variations in temperature, where higher temperatures were observed during summer months and lower temperatures during winter periods. Rainfall analysis showed uneven distribution patterns, indicating periods of heavy rainfall during monsoon seasons and comparatively dry conditions during other months. Similarly, humidity levels were observed to fluctuate based on rainfall and temperature conditions, often increasing during rainy periods and decreasing during dry weather. Wind speed analysis provided additional insights into atmospheric changes and environmental behavior over time.

The system also performed correlation analysis between different weather parameters to better understand their relationships and dependencies. The analysis showed that humidity levels were strongly influenced by rainfall patterns and temperature variations. In several cases, an increase in rainfall corresponded with higher humidity levels and reduced temperatures. These findings helped in understanding the interconnected nature of weather parameters and demonstrated the importance of applying analytical techniques for deeper environmental insights. The use of exploratory data analysis further helped in identifying unusual patterns, sudden variations, and anomalies within the dataset that may not have been immediately visible in raw numerical form.

Visualization played a major role in the effectiveness of the proposed system. The dashboard generated various graphical representations, including line charts, bar graphs, pie charts, and heatmaps, to present weather data in an intuitive and understandable manner. Line charts were used to display temperature trends over time, making it easier to identify seasonal fluctuations and long-term changes. Bar graphs were used to compare monthly and yearly variations in rainfall and humidity levels, while heatmaps helped visualize intensity variations and concentration patterns within the dataset. These visual representations simplified



complex numerical information and allowed users to quickly interpret weather conditions without requiring advanced technical knowledge or statistical expertise.

The interactive features of the dashboard further improved the overall usability and functionality of the system. Users were able to dynamically filter and explore data based on parameters such as date range, location, and weather attributes. This flexibility enabled users to customize the analysis according to their specific requirements and improved the overall user experience. Unlike traditional weather systems that primarily provide static reports or raw numerical outputs, the proposed dashboard offered a more engaging and interactive environment for data exploration. The inclusion of interactive controls and real-time updates made the system more practical and accessible for both technical and non-technical users.

The performance of the dashboard was also evaluated during implementation. The system demonstrated efficient handling of moderate-sized datasets and provided smooth interaction with minimal response delay during visualization and filtering operations. The integration of data preprocessing and optimized visualization techniques contributed to faster processing and improved system performance. The dashboard successfully displayed analytical results in a clear and organized manner, allowing users to access meaningful insights within a short period of time. Compared to traditional weather reporting methods, the proposed system significantly improved data accessibility, clarity, and analytical capability.

Despite the successful implementation and positive outcomes, certain limitations were identified during the study. One of the major limitations is the dependency on external APIs and online data sources for real-time weather information. Any interruption, inconsistency, or unavailability of these sources may affect the reliability and continuity of the system. In addition, incomplete or inconsistent data records can still influence the accuracy of the analysis despite preprocessing efforts. Another limitation is related to scalability, as handling extremely large datasets or continuous real-time streaming data may require additional optimization and computational resources. Furthermore, the current system mainly focuses on descriptive and exploratory analysis and does not include advanced predictive models or machine learning algorithms for weather forecasting. Therefore, the system cannot currently predict future weather conditions or generate automated alerts based on predictive insights.

Overall, the results obtained from this study demonstrate that the integration of data science techniques with interactive visualization provides an effective and practical approach for weather data analysis. The proposed system successfully converts raw meteorological data into meaningful insights through preprocessing, statistical analysis, and graphical representation. The dashboard improves the accessibility, interpretability, and usability of weather data while supporting better understanding of climatic patterns and environmental conditions. The study confirms that data-driven analytical systems can significantly enhance traditional weather monitoring approaches and provide valuable support for applications such as environmental monitoring, climate awareness, research, and decision-making.



V. Future scope

Although the proposed Weather Data Analysis and Visualization Dashboard successfully demonstrate the application of data science techniques for analyzing and interpreting weather data, there are several opportunities for further enhancement and expansion. The current system mainly focuses on descriptive analysis and visualization of weather parameters such as temperature, humidity, rainfall, and wind speed. However, with the integration of advanced technologies and analytical methods, the system can be further developed into a more intelligent, scalable, and efficient platform capable of supporting predictive and real-time decision-making applications.

One of the most significant future enhancements involves the integration of machine learning and predictive analytics techniques. By applying machine learning algorithms such as linear regression, decision trees, random forests, and neural networks, the system can be extended to perform weather forecasting based on historical weather patterns and environmental trends. Predictive models can help estimate future temperature changes, rainfall probability, humidity variations, and extreme weather conditions. This would transform the system from a purely descriptive analytical platform into a predictive decision-support system capable of assisting users in planning and forecasting activities more effectively. Such capabilities would be particularly useful in sectors like agriculture, disaster management, transportation, and environmental planning.

Another important area for future development is the enhancement of real-time data integration. The current system relies on limited external APIs and datasets for weather information. In the future, the dashboard can be connected to multiple real-time APIs and live weather services simultaneously to improve data availability, reliability, and accuracy. Continuous real-time updates would allow users to monitor weather conditions dynamically and access the most recent environmental information without delay. The inclusion of automated refresh mechanisms and streaming data processing techniques can further improve the responsiveness and effectiveness of the system.

The development of a mobile-based application also presents a valuable opportunity for improving accessibility and usability. A dedicated mobile application would allow users to access weather analytics and visualizations anytime and anywhere using smartphones or tablets. Features such as location-based weather monitoring, push notifications, and real-time alerts for severe weather conditions could greatly enhance the practical usefulness of the system. Mobile integration would make the platform more convenient for users such as farmers, travelers, environmental researchers, and emergency response teams who require quick access to weather information in real-world scenarios.

Future research can also explore the integration of Internet of Things (IoT) devices and environmental sensors for collecting more accurate and location-specific weather data. IoT-based weather monitoring stations can



continuously capture atmospheric conditions such as temperature, humidity, pressure, and air quality directly from physical environments. Integrating these sensors with the dashboard would improve the accuracy and granularity of the collected data while enabling localized environmental analysis. Such integration could support smart city initiatives, environmental monitoring systems, and precision agriculture applications.

Scalability is another important area for future enhancement. While the current system performs efficiently with moderate-sized datasets, handling very large datasets and continuous real-time streams may require additional optimization techniques. Future improvements may include the use of cloud computing platforms, distributed databases, and big data technologies such as Hadoop or Spark to support large-scale data storage and processing. This would enable the system to handle weather data from multiple geographical regions simultaneously and support nationwide or global environmental monitoring applications.

The visualization component of the dashboard can also be further enhanced through advanced and interactive visualization techniques. Future versions of the system may include 3D visualizations, geospatial mapping, animated weather patterns, and AI-assisted visual analytics to improve user understanding and engagement. Customizable dashboards can allow users to personalize layouts, select preferred weather parameters, and generate customized reports according to their requirements. Such enhancements would make the system more flexible, interactive, and user centric.

Another potential improvement involves the implementation of alert and notification systems for extreme weather events. The system can be extended to generate automated alerts for conditions such as heavy rainfall, storms, heatwaves, or sudden temperature changes. By integrating predictive analytics with notification systems, users can receive early warnings and take preventive actions in advance. This feature would be especially beneficial for disaster management authorities, agricultural planning, and public safety operations.

Security and data privacy are also important considerations for future development. As the system expands and integrates multiple real-time data sources, proper security mechanisms will be necessary to ensure safe data handling and protection against unauthorized access. Future enhancements may include secure API communication, user authentication mechanisms, encrypted data storage, and role-based access control to improve the reliability and trustworthiness of the platform.

Furthermore, the system can be extended beyond weather analysis to support broader environmental monitoring applications. Additional environmental parameters such as air quality index (AQI), pollution levels, carbon emissions, water quality, and soil conditions can be integrated into the dashboard. This would transform the platform into a comprehensive environmental analytics system capable of supporting sustainability initiatives and climate research activities.



Overall, the future scope of this research lies in enhancing the system through advanced technologies, improving scalability and real-time capabilities, and expanding its applications across multiple domains. The integration of machine learning, IoT, cloud computing, advanced visualization, and predictive analytics has the potential to transform the proposed system into a comprehensive intelligent weather and environmental monitoring platform capable of supporting research, planning, environmental awareness, and data-driven decision-making on a much larger scale.

VI. Conclusion

This research successfully demonstrates the application of data science techniques for analyzing and visualizing weather data through the development of an interactive dashboard system. The study focused on transforming large volumes of raw meteorological data into meaningful and understandable insights by applying a structured workflow consisting of data collection, preprocessing, statistical analysis, exploratory analysis, and visualization. The proposed system effectively handled important weather parameters such as temperature, humidity, rainfall, and wind speed, enabling users to better understand climatic conditions and environmental variations over different time periods.

One of the major contributions of this research is the successful integration of analytical techniques with visualization methods to improve the interpretation of weather data. Weather datasets are often large, complex, and difficult to understand in raw numerical form. Through the use of visualization tools such as line charts, bar graphs, scatter plots, and heatmaps, the system simplified complex datasets into graphical representations that are easier to analyze and interpret. These visualizations helped in identifying important trends, seasonal variations, rainfall distribution patterns, temperature fluctuations, and relationships between multiple weather parameters. Compared to traditional weather monitoring systems that mainly rely on static reports and raw numerical outputs, the proposed approach significantly improved data accessibility, clarity, and interpretability. The interactive dashboard developed in this research further enhanced the overall usability and effectiveness of the system. By allowing users to dynamically filter and explore weather data based on parameters such as date range, location, and weather attributes, the system provided a flexible and user-friendly environment for data analysis. The dashboard enabled users to interact with the data in real time and observe patterns more effectively through dynamic graphical outputs. This feature made the system suitable not only for technical users and researchers but also for non-technical users such as students, farmers, policymakers, and environmental analysts who require simple and actionable insights from weather data.

The research also emphasizes the importance of data preprocessing in any data science application. During implementation, the collected weather datasets contained several issues such as missing values, duplicate records, inconsistent formats, and irregular timestamps. Proper preprocessing techniques such as data cleaning, normalization, formatting, and transformation were applied to improve data quality and consistency. This preprocessing stage played a critical role in ensuring the reliability and accuracy of the analytical results. Without effective preprocessing, the analysis could produce misleading or inaccurate outcomes, thereby reducing the effectiveness of the entire system.



In addition to visualization and preprocessing, the use of statistical and exploratory data analysis techniques helped uncover hidden patterns and relationships within the weather data. The analysis revealed significant seasonal changes in temperature, variations in humidity levels, and uneven rainfall distribution across different periods. Correlation analysis further demonstrated relationships between weather parameters, such as the influence of rainfall on humidity and temperature changes. These findings highlight the effectiveness of data science techniques in extracting valuable insights from complex environmental datasets.

The system also demonstrated efficient performance during implementation and testing. It successfully processed moderate-sized datasets and generated visual outputs with minimal delay, ensuring smooth interaction and quick access to information. The integration of multiple modules, including data collection, preprocessing, analysis, and visualization, into a single unified platform improved the overall functionality and practicality of the system. The study confirms that combining analytical processing with interactive dashboards creates a more effective alternative to traditional weather information systems.

Despite the successful outcomes of the research, certain limitations were identified. The system relies heavily on external APIs and online weather data sources, which may occasionally introduce issues related to data inconsistency, availability, or reliability. Incomplete or inaccurate data obtained from these sources can affect the quality of the analysis. Furthermore, the current system focuses mainly on descriptive and exploratory analysis and does not include advanced predictive analytics or machine learning-based forecasting capabilities. As a result, the system cannot currently predict future weather conditions or generate intelligent recommendations. Another limitation is related to scalability, as handling extremely large datasets or continuous real-time streaming data may require additional optimization techniques and computational resources. Although these limitations exist, the research clearly demonstrates that integrating data science techniques with interactive visualization provides an effective, practical, and user-friendly solution for weather data analysis. The proposed system improves the accessibility and usability of weather information while supporting better understanding of climatic trends and environmental behavior. The study also highlights the growing importance of data-driven approaches in environmental monitoring and decision-making processes.

Overall, the research concludes that the combination of data preprocessing, statistical analysis, and interactive visualization can significantly enhance traditional weather monitoring methods by converting raw meteorological data into meaningful insights. The developed dashboard system provides a strong foundation for future advancements in weather analytics and environmental monitoring. With further improvements such as predictive modeling, machine learning integration, real-time analytics, and IoT-based data collection, the system has the potential to evolve into a comprehensive intelligent weather analysis and forecasting platform capable of supporting a wide range of real-world applications in climate research, agriculture, disaster management, planning, and environmental awareness.



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