AI-Based Weather Forecasting and Natural Language Summary Generation Using Time Series Modeling

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Abstract - Weather forecasting is a critical task with wide-ranging applications in agriculture, transportation, public safety, and climate-sensitive industries. While traditional forecasting methods rely on numerical simulations of physical atmospheric processes, modern data-driven techniques such as machine learning and time series modeling offer accessible alternatives. This research presents an AI-powered weather prediction system that utilizes Facebook Prophet for time series forecasting and integrates Natural Language Processing (NLP) to automatically generate human-readable summaries of predictions. The model forecasts daily minimum temperatures based on historical weather data and converts forecasted data into descriptive monthly insights. Additionally, the system supports basic natural language queries such as "Tell me about July" by extracting intent using rule-based parsing. Our experiments demonstrate that the model delivers accurate forecasts and enhances interpretability, offering a robust tool for non-expert users.

Key Words: Weather Forecasting, Time Series Analysis, Prophet, NLP, Natural Language Generation, Data Science, Monthly Summary, Human-Centered AI

1. INTRODUCTION

Weather forecasting has evolved dramatically over the last century. Classical meteorological models rely on solving complex differential equations that simulate atmospheric conditions. While accurate, these models require extensive computational infrastructure and real-time environmental data. In contrast, time series forecasting models analyze patterns in historical data to make predictions about future values. With the proliferation of accessible data science tools and open-source machine learning frameworks, the field has witnessed an emergence of hybrid solutions that combine the power of AI with the simplicity of statistical modeling.

This paper introduces a hybrid AI-based system designed to forecast minimum daily temperatures using Facebook Prophet, an advanced forecasting library capable of handling seasonality, trends, and missing data. To enhance usability, the system includes an NLP module that interprets model output and presents forecasts in human-readable language. Furthermore, users can interact with the system by typing queries such as "What will the weather be like in December?" The model responds with temperature summaries based on the predicted data. This interactive and interpretable design aims to make weather forecasting more approachable and practical for a wide audience.

2. Related Work

Forecasting techniques traditionally employed in meteorology include ARIMA (AutoRegressive Integrated Moving Average), exponential smoothing methods, and state-space models. While effective in short-term predictions, these techniques often require extensive parameter tuning and struggle with complex seasonal patterns. Machine learning models such as Support Vector Machines (SVMs), Decision Trees, and Recurrent Neural Networks (RNNs) have been applied to weather prediction, especially when considering multiple features like humidity, wind, and atmospheric pressure.

Facebook Prophet stands out due to its automatic detection of seasonality and changepoints, ease of use, and interpretability. Several studies have demonstrated Prophet's effectiveness in business forecasting, stock market predictions, and climate-related applications. However, most implementations end with the generation of numeric results or plots. Few studies explore the combination of forecasting with NLP to enhance accessibility.

Our system fills this gap by integrating NLP-based summary generation, allowing users to comprehend trends and interact with the forecast model via textual commands. This approach bridges the divide between sophisticated analytics and practical, day-to-day usability.

3. Methodology

A. Dataset and Preprocessing

We use the well-known "Daily Minimum Temperatures" dataset, which contains temperature records for Melbourne, Australia, from 1981 to 1990. The dataset is sourced from the Machine Learning Mastery repository and includes two columns: Date and Temperature.

Data preprocessing involves renaming columns to 'ds' (timestamp) and 'y' (value) to align with Prophet's requirements. The date column is converted to datetime format, and null checks are performed to ensure data consistency.

B. Forecasting Model

Prophet models the time series using an additive approach, combining trend, seasonality, and holidays. The general formula is:

$$y(t) = g(t) + s(t) + h(t) + \varepsilon(t)$$

Where:

- $g(t)$: trend function
- $s(t)$: seasonality component
- $h(t)$: holiday effects
- $\varepsilon(t)$: error term

The model is trained on 10 years of historical temperature data and configured to predict temperatures for the next 365 days. Output includes 'yhat' (forecast), 'yhat_lower', and 'yhat_upper' for uncertainty bounds.

C. NLP Summary Generator

The NLP module is rule-based and extracts the month from user input using string matching. For each month, it calculates the average, minimum, and maximum predicted temperatures. It formats this data into a concise summary:

"Forecast for July:
Avg Temp: 8.2°C
Max Temp: 12.9°C
Min Temp: 4.1°C"

This summary helps users understand weather trends without needing to interpret graphs or numeric tables.

D. Visualization

The system uses matplotlib to visualize historical and forecasted temperatures. A second chart shows average predicted temperatures month-wise, allowing identification of seasonal patterns such as warm summers and cold winters.

4. Results and Analysis

The Prophet model effectively captured annual temperature cycles, identifying warmer months (January, February) and colder months (June, July). The forecasts aligned with historical weather patterns in Melbourne. Summaries generated by the NLP module accurately reflected the statistical metrics computed from the forecast data.

In user tests, the system responded to natural language queries with minimal latency. Adding a precomputed 'month' column to the forecast dataframe eliminated the overhead of repeated datetime processing. As a result, user interaction became nearly instantaneous. The visualizations were informative and offered a clear view of forecast trends.

5. Discussion

This study demonstrates the synergy between time series forecasting and natural language interfaces. While Prophet offers a robust framework for predicting future data points, its raw output is typically consumed by data scientists. By incorporating an NLP-driven interface, we enhance the accessibility of AI systems. This creates opportunities for a wider demographic, including farmers, educators, and non-technical professionals, to interact with data-driven tools.

The limitations of the current system include its reliance on historical temperature data alone and the lack of integration with real-time sources.
Furthermore, the rule-based NLP component, though effective, lacks the depth and flexibility of more advanced NLP models. Incorporating a transformer-based language model in the future could enrich the user interaction experience. Despite these limitations, the system is lightweight, easy to implement, and performs well within the scope of its objectives.

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6. Conclusion

This paper demonstrates a practical system for weather forecasting that marries AI-driven prediction with human-centered design. By using

Facebook Prophet for accurate time series modeling and a rule-based NLP layer for natural language output, the system improves both the accuracy and accessibility of weather information.

Such a tool can be valuable in educational settings, small-scale agriculture, or for individuals seeking daily planning support. It stands as an example of how AI can serve human needs beyond raw computation, offering interpretable and actionable insights.

7. Future Work

Future enhancements could include:

- Real-time data integration using APIs (e.g., OpenWeatherMap)
- Voice-based input using speech recognition
- Support for multiple weather features (e.g., precipitation, humidity)
- Deployment as a web or mobile app using Streamlit or Flutter
- Advanced NLP with LLMs for richer summaries

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