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Machine Learning-based Analysis and Prediction of Leap Second Adjustments in Global Timekeeping

Anjali Bisht[1,2], Navraj Poudel[1,2] and Poonam Arora*[1,2]
[1]CSIR-National Physical Laboratory, New Delhi, India
[2]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, India
Email: arorap@nplindia.res.in

The introduction of leap seconds in 1972 aimed to reconcile Coordinated Universal Time (UTC) with Universal Time (UT1), ensuring minimal discrepancy between atomic time and Earth's rotational time. However, the irregular insertion of leap seconds, driven by unpredictable variations in Earth's rotation, has introduced significant challenges for modern infrastructure, including global navigation satellite systems (GNSS), telecommunications, and high-frequency trading. Recent observations indicate a trend reversal in UT1-UTC data, with Earth's rotation accelerating notably since May 2020, raising the unprecedented possibility of a negative leap second. These challenges have sparked international discussions about transitioning to a continuous atomic time scale, as proposed by bodies such as the General Conference on Weights and Measures (CGPM) and the International Telecommunication Union (ITU). While this transition would eliminate the disruptions caused by leap seconds, it raises concerns about the long-term drift between atomic time and astronomical time, highlighting the need for a balanced approach to global timekeeping [1-3].

To address these challenges, this study employs advanced machine learning (ML) techniques, including Long Short-Term Memory (LSTM) neural networks and the Prophet time-series forecasting model, to predict (UT1-UTC) leap second adjustments. The LSTM model, trained on data from May 2020 to May 2023, utilizes three stacked LSTM layers with 50 memory units each, followed by a dense layer for final predictions. The dataset is pre-processed by normalizing values and splitting it into training (80%) and testing (20%) sets, with a window size of 35 for input-output sequence formation. The model is trained for 100 epochs using the Adam optimizer, minimizing Mean Squared Error (MSE). In 2023, the model was used to predict UT1-UTC values for the next 365 days, and its performance was evaluated using root mean squared error (RMSE). While the LSTM predictions follow the actual UT1-UTC trend, they exhibit higher error compared to the Prophet model, which proves more suitable for long-term forecasting due to its ability to capture seasonal patterns and handle outliers effectively [4].

In this study, we present a comprehensive comparison between the predicted UT1-UTC values for 2024 and 2025 and the actual observed data. This analysis highlights the strengths and limitations of the LSTM and Prophet models, providing valuable insights into their performance. Furthermore, we propose modifications to the AI-ML models to enhance their predictive accuracy, ensuring better alignment with observed trends. These improvements aim to refine the forecasting of UT1-UTC, reducing the need for frequent leap second adjustments and contributing to a more stable global timekeeping system.

In conclusion, this work highlights the transformative potential of AI-ML techniques in precision timekeeping and Earth sciences, while advocating for a robust and stable global time standard that meets the demands of modern infrastructure and future technological advancements.

References:

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