Sequential Dihybrid Recurrent Neural Network for Solar Radiation Prediction: A Path to Renewable Energy Sustainability in Nigeria

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INTRODUCTION

Accurate solar radiation projections can improve the efficiency of solar energy systems, optimize energy output, and help ensure the long-term viability of renewable energy projects. The purpose of this research is to develop a hybrid model that combines the strengths of both LSTM and GRU models to improve the quality of the forecast. Building on previous research, this study aims to improve understanding of Nigerian climate patterns and trends by identifying perceptions of solar radiation variability and change through Recurrent Neural Networks (RNN) such as Long Short-term Memory (LSTM) and Gated Recurrent Unit (GRU).

MATERIALS AND METHODS

This study examined historical climate data from the Nigerian Meteorological Agency's (NiMeT) database over a 31-year period. Monthly data were retrieved for seven cities in Nigeria: Ikeja, Sokoto, Maiduguri, Enugu, Ilorin, and Port Harcourt. The LSTM and GRU models were built using hyperparameter tuning to determine the best models. Both LSTM and GRU networks can accurately predict complex temporal relationships in data.

RESULTS AND DISCUSSION

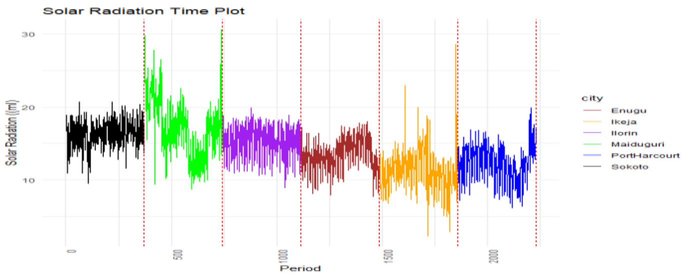

Figure 1: Time plot on Solar Radiation over Enugu, Ikeja, Ilorin, Maiduguri, Port-Harcourt, and Sokoto

The plot shows that solar radiation levels vary significantly across cities, with Enugu and Port Harcourt showing more variability. Maiduguri and Ilorin show more consistent levels, indicating seasonal or cyclical weather patterns. The LSTM and GRU models show poor performance with low R^2 values, while the hybrid model outperforms them in all metrics, indicating its superior accuracy and efficiency in forecasting the solar radiation dataset.

Table 2: Performance metrics on the three models

Architecture	**MSE**	**MAE**	**RMSE**	R^2
hybrid	0.0003	0.0137	0.0137	0.9976
GRU	0.0210	0.1088	0.1088	0.6311
LSTM	0.0382	0.1466	0.1466	0.3365

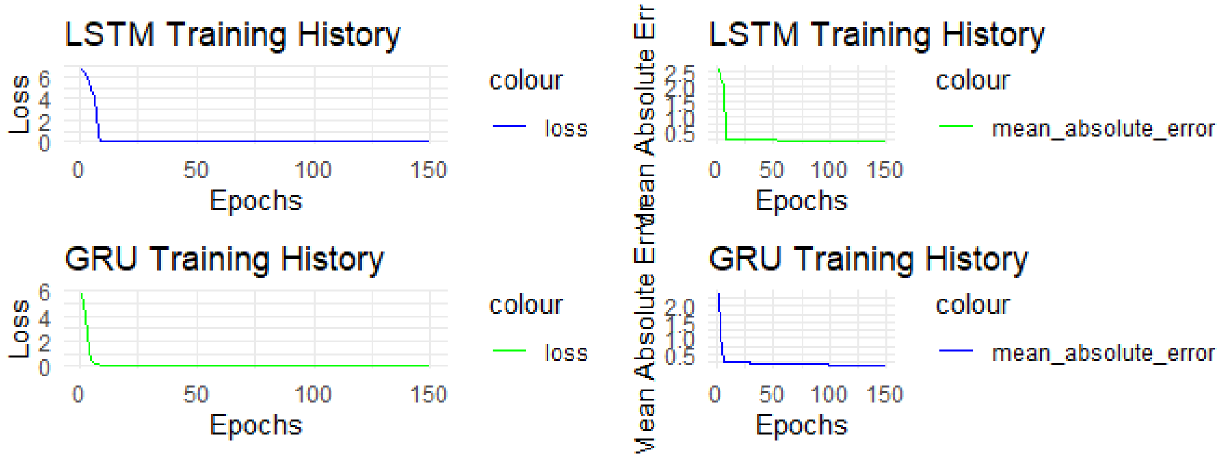

Figure 2: Training History of LSTM and GRU Models

The stabilization of further training narrows down and indicates that errors are not significantly reduced by additional training. The convergence of training and validation loss suggests good generalization capabilities.

PREDICTIONS AND RESIDUALS

LSTM and GRU Models on Test Dataset

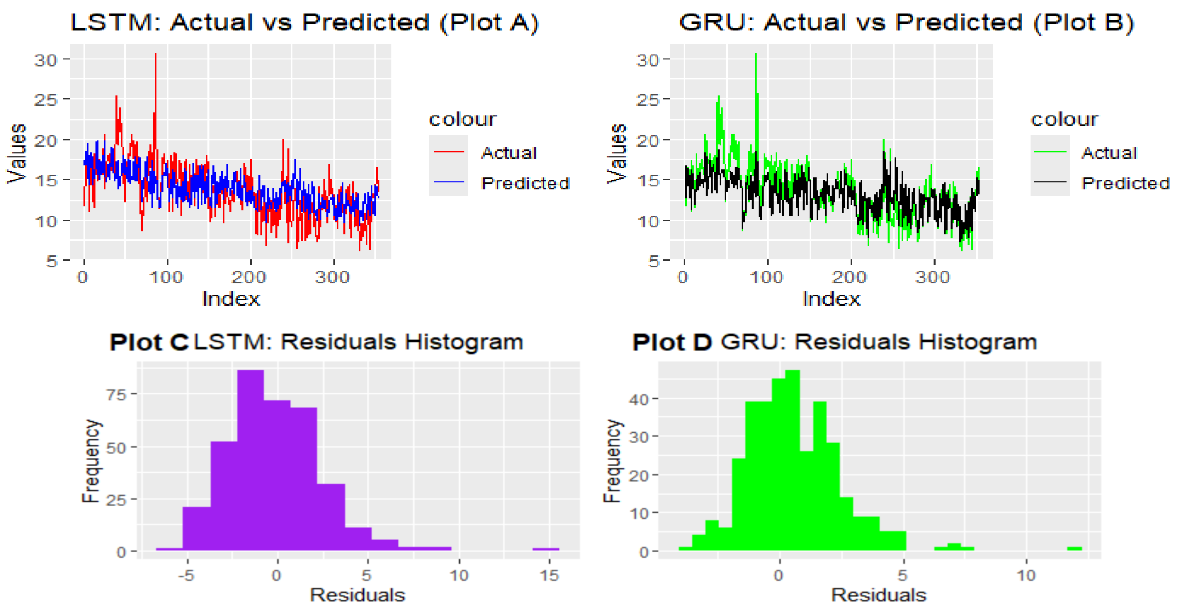

Figure 3 illustrates that the GRU model, more accurately predicts actual data compared to LSTM. While both models generally produce residuals near zero, GRU exhibits fewer outliers and a narrower spread of residuals, indicating superior prediction precision and consistency.

CONCLUSIONS

By successfully capturing convoluted temporal patterns, the panel hybrid RNN model—which combines LSTM and GRU—improves the accuracy of solar radiation predictions and is a beneficial tool for maximizing Nigeria's solar energy resources and assisting with sustainability initiatives. However, further improvements can be made by integrating real-time solar radiation data, expanding the model's application to larger datasets, and combining it with other machine learning techniques to enhance its predictive capabilities.

Keywords: Hyperparameter tuning, Meteorological Data, Renewable Energy, Sequential Recurrent Neural Network, Solar Radiation Prediction, Time Series Forecasting