

The Role of Attention Mechanisms in Deep Learning for Hourly Solar Forecasting: A Case Study in Tropical Brazil

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INTRODUCTION & AIM

The expansion of photovoltaic generation is a strategic pillar of Brazil's National Energy Plan 2050 [1]. However, the high intermittency of solar irradiance in tropical climates poses challenges for grid stability, demanding robust forecasting methods. While Deep Learning models like LSTM are established in the literature, the specific impact of bidirectional processing and attention mechanisms on univariate forecasting remains under-explored in this region [2]. This study addresses this gap by rigorously evaluating four architectures (LSTM, BiLSTM, and their attention-enhanced variants) using data from João Pessoa/PB, aiming to identify the optimal model for regional grid integration.

METHOD

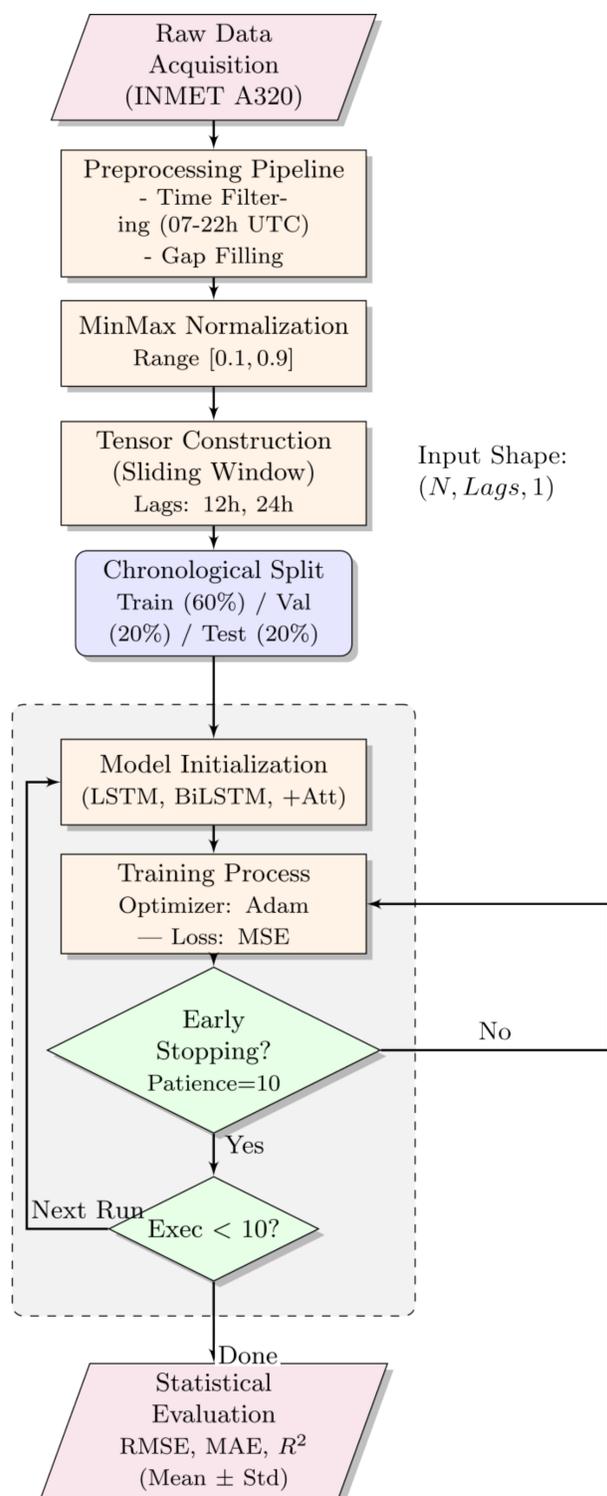


Figure 1: Flowchart of the proposed methodology for solar irradiance forecasting.

RESULTS

Model	RMSE (W/m^2)	MAE (W/m^2)	R^2
BiLSTM	94.63 ± 3.42	53.25 ± 3.33	0.915 ± 0.009
LSTM	95.13 ± 2.79	53.23 ± 2.87	0.914 ± 0.008
BiLSTM-Att	96.07 ± 2.75	53.80 ± 3.35	0.913 ± 0.008
LSTM-Att	98.30 ± 3.13	55.18 ± 2.28	0.908 ± 0.008

Table 1: Consolidated performance metrics (Mean ± Standard Deviation) for all years

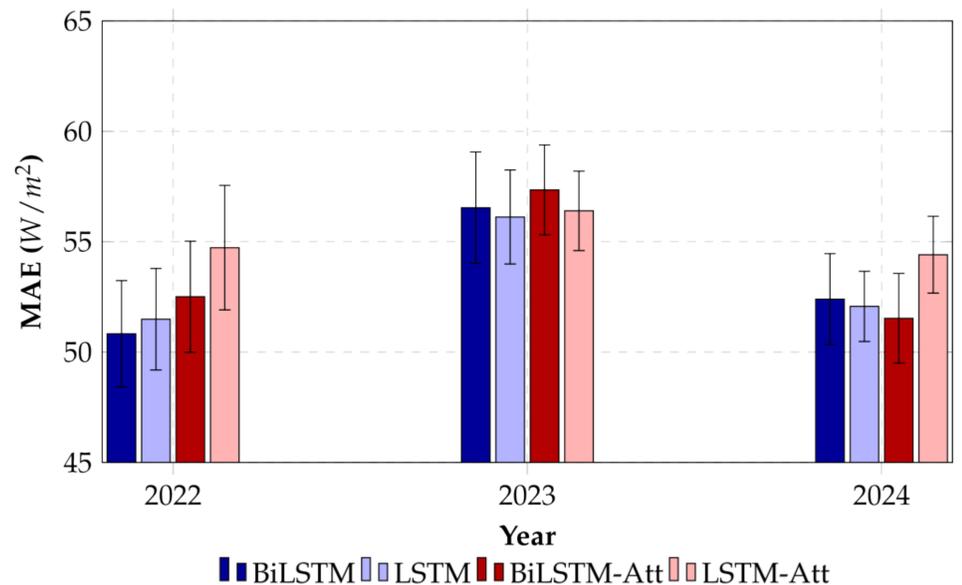


Figure 2: Annual MAE values with error bars representing standard deviation.

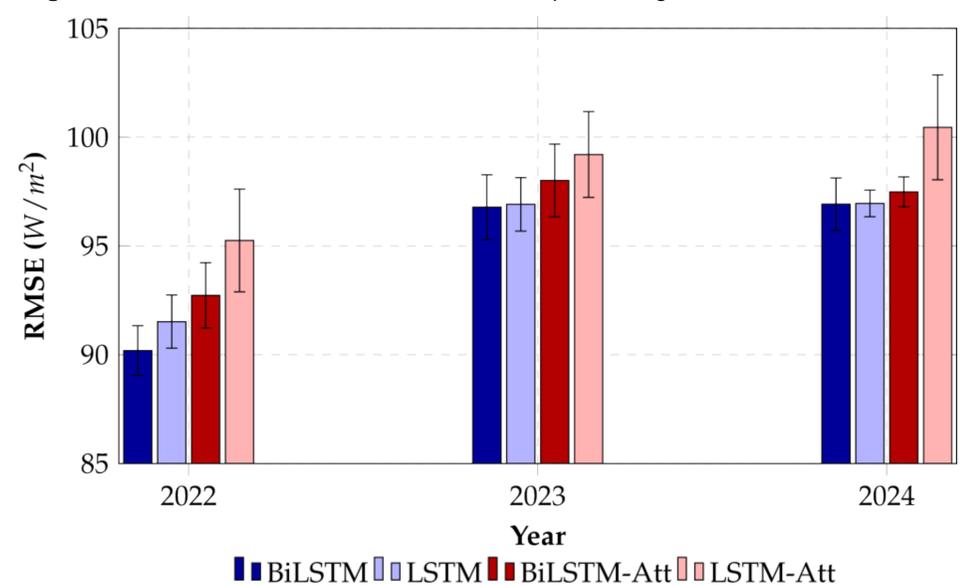


Figure 3: Annual RMSE values with error bars representing standard deviation.

CONCLUSION

Results demonstrate that the BiLSTM architecture consistently outperformed standard LSTM and attention-based variants. Contrary to recent trends, integrating attention mechanisms degraded performance, suggesting they introduce noise in univariate series. Consequently, BiLSTM is identified as the most robust solution for operational forecasting in tropical Northeastern Brazil.

REFERENCES

- [1] <https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/Plano-Nacional-de-Energia-2050>
[2] <https://doi.org/10.3390/app12073510>