Field Testing and Data-Driven Modeling of Variable Refrigerant Flow (VRF) System in Buildings

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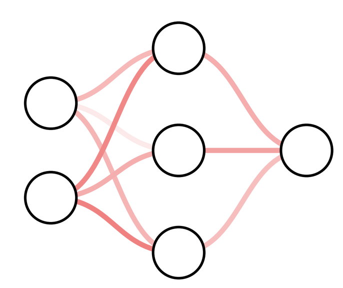
Introduction

- Buildings account for about 30% of U.S. primary energy use[1] and 37% of global CO_2 emissions[2].
- HVAC systems contribute about 50% of a building's total energy consumption[3].
- Optimized control of VRF system requires an accurate model for power consumption.
- This study presents a long-short-term memory (LSTM) model to accurately predict the power consumption of a VRF system based on the measured input features.

Which data-driven models offer the best trade-off between accuracy, computational efficiency, and data efficiency for modeling VRF systems?



Methods

- One year of field data covering all seasons was used to train the data-driven models.
- These models map selected input features to the VRF system's power consumption.
- Model hyperparameters were optimized using Bayesian optimization.

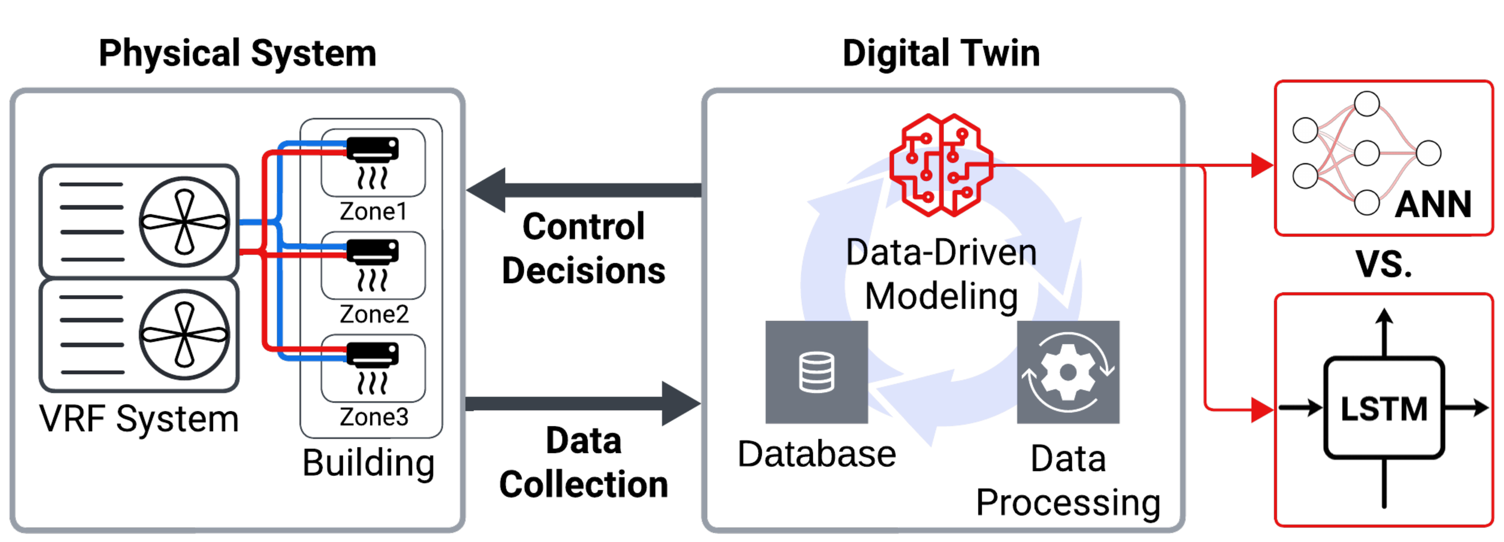
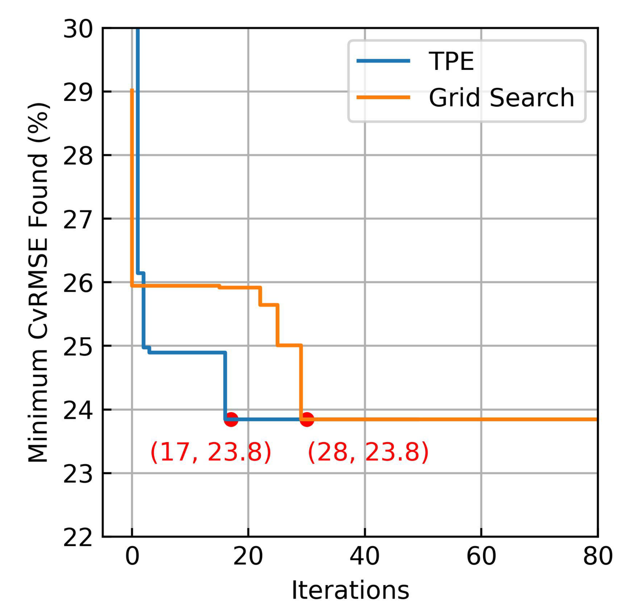


Figure 1. Flowchart of data collection, processing, and model development.

Results

Hyperparameter tuning via Bayesian optimization (TPE)[4] is more efficient than exhaustive search



Hyperparameters of the models.

Models	Hyperparameters	Search Space
ANN/LSTM	Batch size	[2^4, 2^5, …, 2^{10}]
	Layer dimension	[1, 2]
	Neurons per layer	[2^4, 2^5, …, 2^{10}]
Decision Tree (DT)	Minimum samples split	[1, 2, …, 50]
	Minimum samples leaf	[2, 3, …, 50]

Figure 2. Minimum error observed during hyperparameter optimization.

LSTM achieved greater accuracy with fewer trainable parameters than ANN

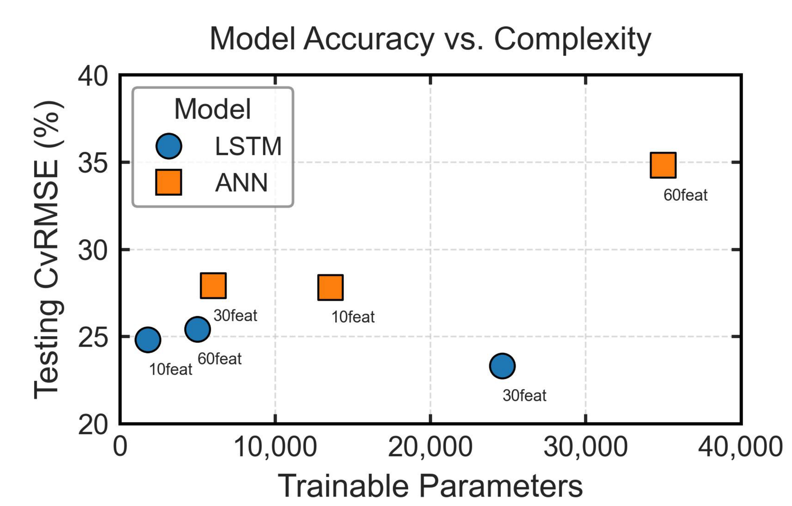


Figure 3. Models error vs. number of trainable parameters.

LSTM maintained low prediction residuals even in data-scarce regions (high-PLR)

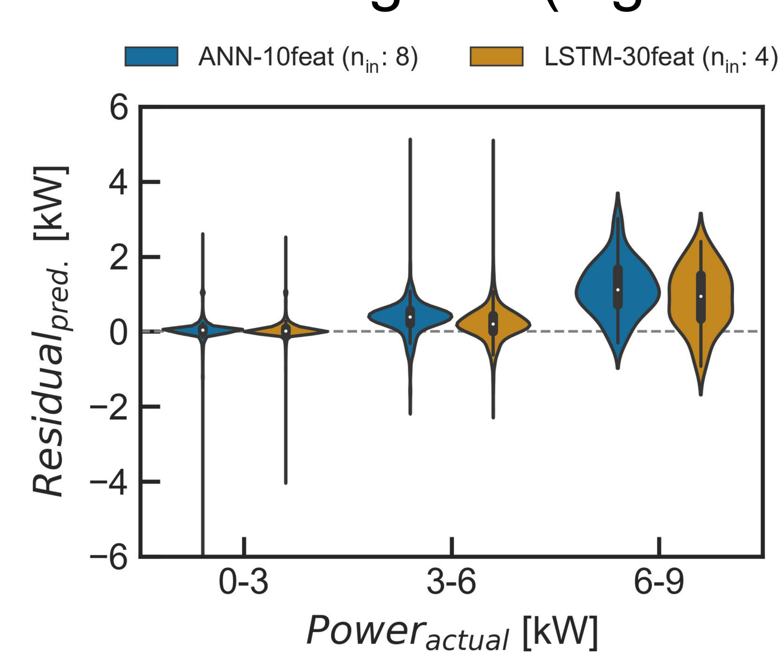


Figure 4. Distribution of prediction residuals by bin.

LSTM achieved a lower CvRMSE (22%) in power consumption prediction compared to ANN (27%) and DT (28%)

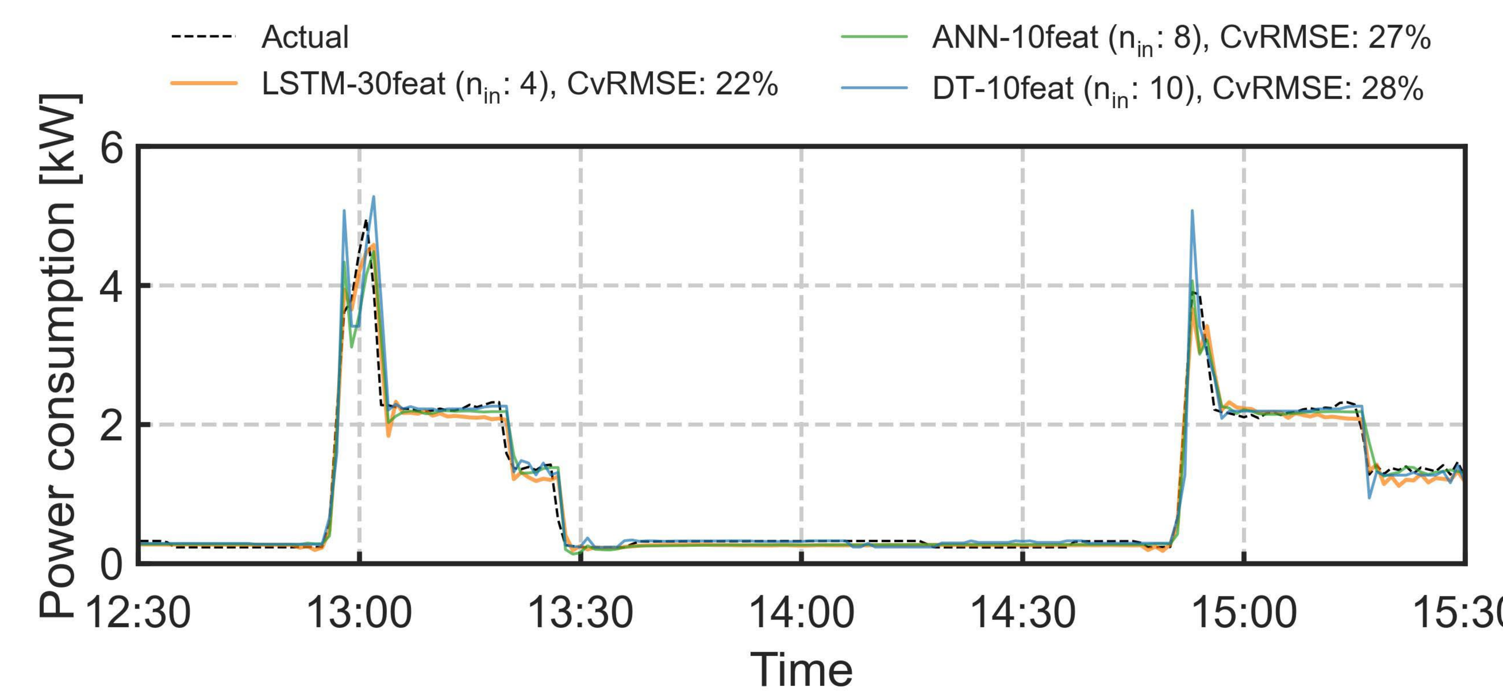
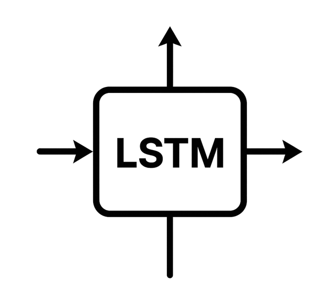


Figure 5. Model predictions for an out-of-sample winter day.

Conclusions

- LSTM-30feat achieved the highest accuracy among all models (CvRMSE: 23.3 %).
- LSTM is preferable to ANN in terms of both model complexity and accuracy.
- LSTM-30feat demonstrates greater tolerance to data scarcity.



LSTM is preferred over ANN for optimized control due to its higher accuracy, lower complexity, and greater data efficiency

Acknowledgement

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[1] EIA, 2023. https://www.eia.gov/tools/faqs/faq.php?id=86&t=1
[2] NREL, 2022. https://www.nrel.gov/docs/fy22osti/81670.pdf
[3] EIA, 2018. https://www.eia.gov/energyexplained/use-of-energy/commercial-buildings.php
[4] Bergstra, J., Bardenet, R., Bengio, Y., K´egl, B., 2011. Algorithms for Hyper-Parameter Optimization. Advances in Neural Information Processing Systems. Curran Associates, Inc.