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Artificial neural network-based modeling for early-stage daylight and energy multi-objective optimization

Multi-objective optimization provides a Pareto front, representing a set of optimal design solutions that balance multiple design objectives. Multi-objective optimization often involves iterative simulations and evaluations of numerous design alternatives. However, evaluating multi-objective optimized solutions is challenging due to the time-consuming nature of building performance simulation. This can be computationally demanding at the conceptual design stage, especially involving energy modelling and ray-trace calculation. Although machine learning-based models have been explored to reduce simulation time, their capability for multi-objective optimization is limited. To address these challenges, this study proposes an artificial neural network-based modelling approach for predicting annual daylight and energy performance in the early design process. Then, the developed ANN-based models were integrated with NSGA-II optimization algorithms to generate a Pareto front, representing the trade-offs between daylight and energy performance. The proposed workflow, encompasses feature selection, feature engineering, and hyperparameter optimization, which improves the model's generalization capability. The ANNs models were trained to model the relationship between 11 design parameters (e.g., room dimensions, orientation, WWR, shading parameters etc.) and multiple objective functions (daylight metrics, energy consumption). The developed prediction models were validated against Radiance and OpenStudio energy simulation results using a high-accuracy setting. The model attained R2 scores of 0.944, 0.980 and 0.991, MAE scores of 1.77, 1.12 and 3.07, RMSE scores of 2.40, 1.70 and 4.67, for UDIa, UDIs and Cooling EUI (kWh/m2), respectively. Notably, the model achieved this accuracy while being 40 times faster than conventional optimization methods. By integrating this modelling approach into the early design environment, architects can make informed decisions to optimize building form and fenestration, ultimately reaching design solutions that reduce energy consumption without compromising daylighting quality or vice versa. Future work may involve expanding the model to incorporate additional parametric room modules, further enhancing its versatility.

Keyword 1

Neural Network

Keyword 2

Multi-Objective Optimization

Keyword 3

Building Performance

Keyword 4

Daylight

Keyword 5

Energy

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