Deep Neural Network Architectures for Component-Based Machine Learning Model in Building Energy Predictions

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Abstract. Artificial Neural Networks (ANN) are a universal approximator for any non-linear function. However, ANN approximation strongly depends on the architecture, i.e. the structure of the neurons and the training methods. This paper evaluates ANN architectures to model components that represent a building for its energy prediction. ANN architectures evaluated are one-hidden layer neural network (NN), deep NN and stacked autoencoder deep NN. The performance of these ANN architectures is assessed against Random Forest models. Results indicate that ANN methods increase the performance in percentage of coefficient of determination (R^2) between 0.57% to 9.65% compared to Random Forest models. Within ANN architectures evaluated, deep NN architectures performed better for most cases.

1 Introduction

Energy performance analysis is becoming an important element within a building design process. The need for having accurate prediction is raising with stringent sustainability requirements and use of energy analysis by various stakeholders. Limitations of current modelling practices are (1) presence of performance- and prediction gaps (Singaravel & Geyer, 2016) (2) detailed simulations are time-consuming and requires a lot of as-built information which is typically not available during design stages.

Developing buildings that are energy-efficient throughout its lifecycle, requires it to be designed and operated with energy-efficiency as an outcome. Building performance evaluation plays a major role in keeping it energy-efficient throughout its lifecycle. Performance is evaluated through Building Energy Models (BEM) during its design and typically through data models during the operational stage (ASHRAE, 2013). The shift from BEM to data models makes it hard to compare the results generated during design and operational stages of a building. Hence, having models that can be used throughout a building's lifecycle can be beneficial. Challenge with data collected during the operational stage is that the data can be noisy which could affect the performance of the models.

Machine learning models (MLMs) can capture interactions observed within detailed simulation models with simple input structure (Horsey, et al., 2016). High calculation speed together with high accuracy makes it an ideal alternative for detailed simulations in certain phases of design. Typical methodology to develop MLM for energy prediction is to have a single model with representative inputs. Limitations of this approach are (1) the inability to quantify the reason for a prediction and (2) the validity restricted to the dataset used to develop it. These limitations are overcome through component-based MLM approach, which gives the ability to quantify the reason for a prediction and increases the reusability of MLMs in a new situation (Singaravel, et al., 2017).

Machine learning (ML) algorithms available ranges from simple curve fitting models to more complex models like Artificial Neural Network (ANN). In this paper, ANN architectures are evaluated as a potential method for working with hourly non-linear data generated from detailed BEM; as ANN offers the following benefits over other ML algorithms: