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CNN vs. DNN: comparing the two neural networks performance in predicting building operational energy with respect to the building shape

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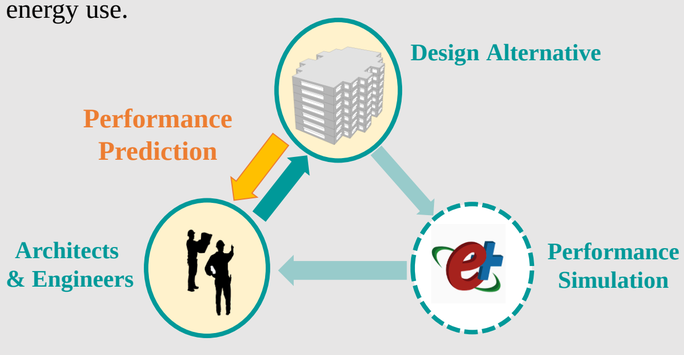
Abstract

From an architectural standpoint, an often overlooked, nonetheless key contributor, to a building's operational energy use is the building shape. Generally, building shape is not approached in tandem with an energy-wise design decision. One of the reasons is that making an energy-wise decision at early stages of the design is not very straightforward since the solution pool is extremely large, and it is hard to find a trend for different shapes, especially, self-shaded shapes which may have contradictory effects on building cooling, heating, and daylighting performance. These complexities call for an efficient method considering time and resources limitation. Deep Learning methods, which are recently being employed in architectural design research, can be used to help designers in early stages of the design to efficiently evaluate building energy performance. The intention of this study is to evaluate firstly, the applicability of Deep Learning in general in predicting building operational energy with respect to the building shape, and secondly, the efficiency of image-based Deep Learning methods in such prediction. In this regard, two different Deep Learning algorithms; Convolutional Neural Network (CNN) that employs images as the input and Deep Neural Network (DNN) that are fed with numbers as the input are compared in terms of complexity, time, and performance.

Research Significance

Regarding that the possibility of an energy-wise design approach emerges at the early stages of the design process, where the designer produces building design representations including sketches, schematic floor plans, elevations, sections, etc., it will be highly valuable if the Deep Learning model can employ such graphics as the input to predict the operational energy use.



Simulation Vs. Prediction

- Time
- Cost
- Expertise

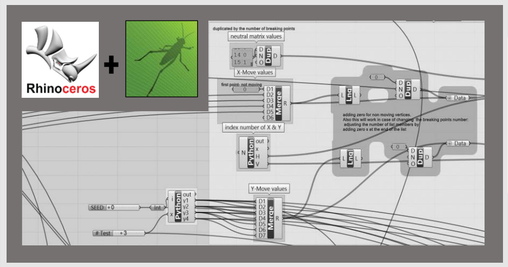
Deep Learning models Can be used to predict buildings performance while saving time, cost.

Research Goals

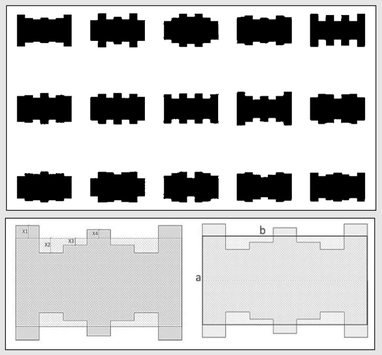
The goal of this study is to confirm whether Deep Learning methods are able to efficiently predict building operational energy with respect to the building shape in lieu of building energy simulations. Then, given the benefits of the image-based Deep Learning methods for architects and designers, this study investigates whether CNN as an image-based method can perform as efficient as DNN in such prediction.

Experiment Design

Training/testing data generation:



Changing only 4 parameters; x1, x2, x3, and x4, while the area is kept constant.



Experiment A

(X1, X2, X3, X4) → DNN Model → Predicting Energy Use → Loss calculation

Energy Plus simulation

Experiment B

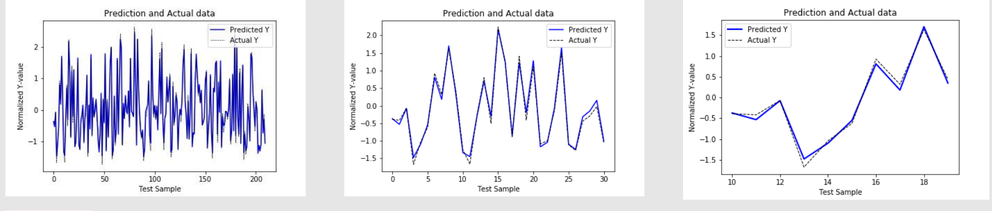
Generated shapes → CNN Model → Predicting Energy Use → Loss calculation

Results & Analysis

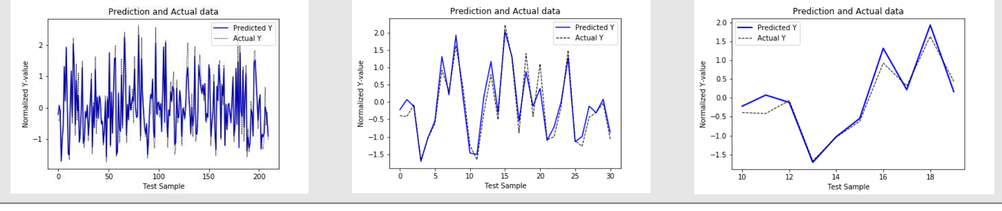
Comparing the two models in terms of complexity, number of layers (number of parameters), number of required epochs, batch size and loss as the performance measures to evaluate the predictive power of the two model:

Model	Dataset size	Number of Parameters	Number of Epochs	Batch size	Loss
DNN	1050	73	100	32	**0.0196**
CNN	1050	10,625	100	32	**0.3229**

DNN The DNN model predicts the building energy use with a loss value equal to 0.02.



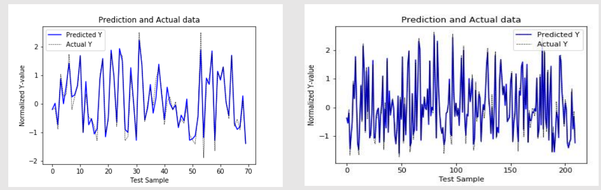
CNN The CNN model predicts the building energy use with a loss value equal to 0.32.



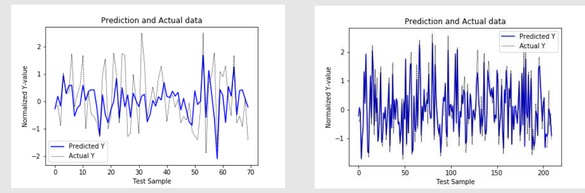
Discussion

Dataset size:

	Dataset size	Number of Parameters	Number of Epochs	Batch size	Loss
DNN	**350**	73	100	32	**0.0466**
	1050	73	100	32	**0.0196**



	Dataset size	Number of Parameters	Number of Epochs	Batch size	Loss
CNN	**350**	73	100	32	**0.5605**
	1050	73	100	32	**0.3229**



Reduce Number of Parameters:

	Dataset size	Number of Parameters	Number of Epochs	Batch size	Loss
CNN	1050	**10,625**	100	32	**0.3229**
	1050	**2,113**	100	32	**0.3299**

Conclusion & Future Work

The comparison of the two models shows that a DNN model surpasses a CNN model in simplicity, time, and the mean squared error, whereas the CNN requires a deeper architecture and is not yet able to perform as well as the DNN model. However, the advantage of CNN for employing images as inputs and thus a better visual connection between the designer and the design evaluation process, urges us for further exploration for finding methods to improve the CNN performance for the purpose of this study.

Acknowledgements

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References

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