A Review of Model-Based Multi-Objective Optimisation Algorithms

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Abstract
Architectural design is a multi-faceted problem with complex interrelations between variables. Naturally, such problems require complex solutions which can be performed in a time and resource-efficient manner utilising technological advancements. In this paper, the demand for multi-objective optimisation and model-based optimisation solutions for architectural design will be reviewed. In addition, the strengths of these methods will be summarised.
Keywords: multi-objective optimisation, model-based optimisation, evolutionary algorithms, surrogate models

In the field of architectural design and engineering, often a set of aspects need to be optimised for the sake of sustainable and efficient design. These aspects include energy use, structural capacity, space allocation and daylight (Ekici, 2019; Wortmann, 2017). Since architectural design is a complex and multi-faceted task where a variety of aspects affect the performance of the designed object, it poses a multi-objective problem (Ekici, 2019 as cited in Shi & Yang 2013). Such multi-objective problems can be addressed by optimising a variety of parameters simultaneously and determining Pareto optimal solutions for the posed problem (Deb, 2011). There are multiple methods for multi-objective optimisation and all have different characteristics.

Optimisation can be performed by using model-free and model-based strategies. Model-based strategies differ from model-free methods in terms of computation time, resources and accuracy. Wortmann (2017) states that model-based optimisation is a time-efficient strategy utilising machine learning principles while resulting in a more accurate model compared to simulation-based methods. With this approach, the model is updated with exact results during each iteration while looking for promising alternatives as noted in the same paper. Overall, model-based strategies bring a more time-efficient and accurate solution to multi-objective problems concerning architectural design.

There are multiple model-based multi-objective optimisation methods. These methods include model-based evolutionary algorithms and surrogate models. Firstly, model-based evolutionary algorithms (MBEA) are evolutionary algorithms (EA) where the heuristics operators are replaced by machine learning models and where potential solutions are used to train the model from current data samples (Cheng et al, 2018). MBEAs are developed due to EAs lacking the ability to learn the structures of the optimisation problems as a result of their operators being based on fixed heuristic rules as stated in the same paper. Surrogate-assisted evolutionary algorithms are an example of MBEAs where computationally efficient models are used instead of computationally expensive models (Cheng et al, 2018). Secondly, Surrogate models are created by simulating the first set of sample points and using the output for the creation of the model (Carreras et al 2016). The same authors (2016) state that surrogate-based algorithms are especially beneficial when they are used along with optimisation algorithms, as they provide a faster and computationally less challenging solution to multi-objective optimisation in building design compared to simulation-based methods.

In conclusion, building design can be approached as a multi-objective optimisation

problem to ensure sustainable and efficient use of resources. However, due to the multitude of objectives and complexity of the problem, model-free simulation-based methods exhaust a vast amount of time and computational resources. Therefore, model-based multi-objective optimisation solutions, such as model based evolutionary algorithms and surrogate models, are beneficial to address such optimisation problems.

Bibliography

Carreras, J., Pozo, C., Boer, D., Guillén-Gosálbez, G., Caballero, J. A., Ruiz-Femenia, R., & Jiménez, L. (2016). Systematic approach for the life cycle multi-objective optimization of buildings combining objective reduction and surrogate modeling—ScienceDirect. https://doi.org/10.1016/j.enbuild.2016.07.062.

Cheng, R., He, C., Jin, Y., & Yao, X. (2018). Model-based evolutionary algorithms: A short survey. *Complex & Intelligent Systems*, *4*. https://doi.org/10.1007/s40747-018-0080-1

Deb, K. (2011). Multi-objective Optimisation Using Evolutionary Algorithms: An Introduction. In L. Wang, A. H. C. Ng, & K. Deb (Eds.), *Multi-objective Evolutionary Optimisation for Product Design and Manufacturing* (pp. 3–34). Springer. https://doi.org/10.1007/978-0-85729-652-8_1

Ekici, B., Çubukçuoglu, C., Turrin, M., & Sariyildiz, I. S. (2019). Performative computational architecture using swarm and evolutionary optimisation: A review. *Building and Environment*, *147*. https://doi.org/10.1016/j.buildenv.2018.10.023

Pereira, J. L. J., Oliver, G. A., Francisco, M. B., Cunha, S. S., & Gomes, G. F. (2022). A Review of Multi-objective Optimization: Methods and Algorithms in Mechanical Engineering Problems. *Archives of Computational Methods in Engineering*, *29*(4), 2285–2308. https://doi.org/10.1007/s11831-021-09663-x

Shi, X., & Yang, W. (2013). Performance-driven architectural design and optimization technique from a perspective of architects. *Automation in Construction*, *32*, 125–135. https://doi.org/10.1016/j.autcon.2013.01.015

Wortmann, T. (2017). Model-based Optimization for Architectural Design—Optimizing Daylight and Glare in Grasshopper. *Technology|Architecture + Design*, *1*, 176–185. https://doi.org/10.1080/24751448.2017.1354615