Design space exploration for high-performance greenhouse design

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Abstract

The design of high-performance buildings has its roots in principles and rules of thumb but has recently been augmented by simulations in structural, lighting, and thermal performance. By integrating simulation programs with parametric frameworks, designers gain additional insight into complex design problems. Sampling and multi-objective optimization (MOO) techniques have demonstrably offered ways to systematically and widely explore complex design spaces for high-performance buildings [1]. Because of its inherent design complexity, particularly in tradeoffs between thermal and lighting performance, the greenhouse constitutes one such high-performance building that could benefit from the application these techniques that permeate the design of other high-performance structures. The use of light and energy simulations for evaluating the performance of agricultural spaces, such as [2], are not uncommon; however, few to no existing work describe how sampling or optimization techniques participate in the greenhouse design process by enabling an exploration of the complex design space.

This paper presents a case study in utilizing design space exploration techniques for the design of a greenhouse that extends the growing season for vegetables in Portola Valley, California. The work synthesizes disparate fields of research: greenhouse design and performance-driven early-stage design.

The design variables of the problem relate to geometry and glazing ratio; design objectives are based on structural, lighting, and thermal performance. Design space explorations are conducted to test greenhouse design rules of thumb, such as the importance of south-facing surfaces and the tradeoff between lighting and thermal performance that dictates glazing ratios. The results demonstrate how design space exploration techniques can not only validate but also augment the rules of thumb, potentially enabling greenhouse designers to improve greenhouse performance beyond conventional design approaches.

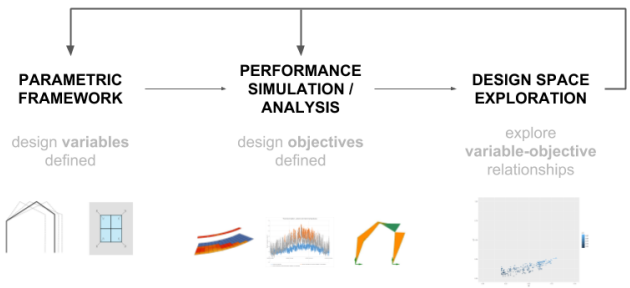

Fig. 1. Methodology for incorporating design space exploration in early-stage greenhouse design.

References

[1] N. C. Brown and C. T. Mueller, "Design for structural and energy performance of long span buildings using geometric multi-objective optimization," *Energy Build.*, vol. 127, pp. 748–761, Sep. 2016.

[2] K. Benis, C. Reinhart, and P. Ferrão, "Development of a simulation-based decision support workflow for the implementation of Building-Integrated Agriculture (BIA) in urban contexts," *J. Clean. Prod.*, vol. 147, pp. 589–602, Mar. 2017.