Combined Super-Structured and Super-Structure Free Optimisation of Building Spatial Designs

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Abstract. This paper proposes a new method for multi-disciplinary optimisation of building spatial designs in the preliminary design stage. First it discusses two recently developed building spatial design optimisation methods, one using a super-structured approach and the other applying a super-structure free approach. Subsequently, a combination of the two methods into a new hybrid method is presented. A case study is demonstrated to compare the three methods based on their performance and the characteristics of their design evolution. First results show that the hybrid method could aid in the effective exploration of large design search spaces by selecting more confined design search spaces based on engineering knowledge.

1. Introduction

The process of building design optimisation is still strongly dependent on input from numerous engineers and designers, simply because the design search space is too large to be overseen by any single stakeholder. This limitation motivates computer scientists to constantly develop new techniques that try to find the global optimum by considering as many solutions as possible without bias. Taking into account every possible solution is, however, computationally infeasible. This paper proposes a new method that uses engineering knowledge to steer the process into interesting sub-domains of the design search space to increase the efficiency of and limit the strain on optimisation algorithms.

One domain in the research on optimisation focuses on multi-objective optimisation by use of evolutionary algorithms, which find a subset of designs to approximate the Pareto optimal front in a predefined search space. Here, a Pareto optimal front is a set of solutions that are characterized by being non-dominated, i.e. no other solutions are defined that perform better for any objective without there being a decrease of performance for any of the other objectives first. State-of-the-art optimisation algorithms such as NSGA-II (Deb *et al*, 2002) or SMS-EMOA (Beume *et al*, 2007) use random selection of solutions and random mutation or crossover on previously found solutions to find the Pareto front. The Hypervolume-based Subset Selection Problem (HSSP), as presented by Kuhn *et al* (2016) and Bringmann *et al* (2014) focuses on the selection of the solutions: If the found Pareto Front Approximation (PFA) contains more points than desired, a reduction should take place; if—on the other hand—fewer points than desired are found, all non-dominated and a diverse selection of dominated points can be selected to reach the desired number.

A drawback of evolutionary algorithms is that they are computationally costly when a rigorous search of large search spaces is attempted. So-called heuristic methods do not have this drawback, as they use a directed and thus fast way to obtain improved designs from the design search space. Heuristic methods are, however, prone to finish the search process when they find a local optimum, rather than the global optimum. An example of a heuristic method is the simulation of Co-evolutionary Design (CD) processes. This method tries to simulate evolutionary processes that are seen in nature where two species interact in a manner where they depend on each other in their evolution. Maher & Tang (2003) present a general method