Hypervolume Gradient Ascent for Memetic Building Spatial Design Optimisation

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Creating a building spatial design involves the cooperation of many engineering experts from different disciplines. Limited knowledge about other disciplines frequently leads to a negative impact on the design with respect to those other disciplines whenever an expert makes changes to improve the design for their own discipline. Automated multi-objective building spatial design optimisation may alleviate this issue. In [1] a mixed integer representation for the bi-objective case, considering structural and energy efficiency, was proposed. Various constraints ensure the validity of the building design, but impede standard evolutionary operators, resulting in the introduction of tailored operators for SMS-EMOA in [2].
In traditional optimisation exact algorithms such as the gradient ascent method are used to quickly find exact optima. Despite the issues these techniques have, for instance with multimodal or irregular landscapes, they are still useful for swift identification of local optima. In multicriteria optimisation the goal is to identify the Pareto optimal front, a set of points. Gradients were however only computed for single points rather than sets of points. One way to measure the quality of a Pareto front approximation is the hypervolume indicator. The work of [3] describes the hypervolume gradient which allows a set of points to both be moved towards the Pareto front, and to be distributed well across the Pareto front.

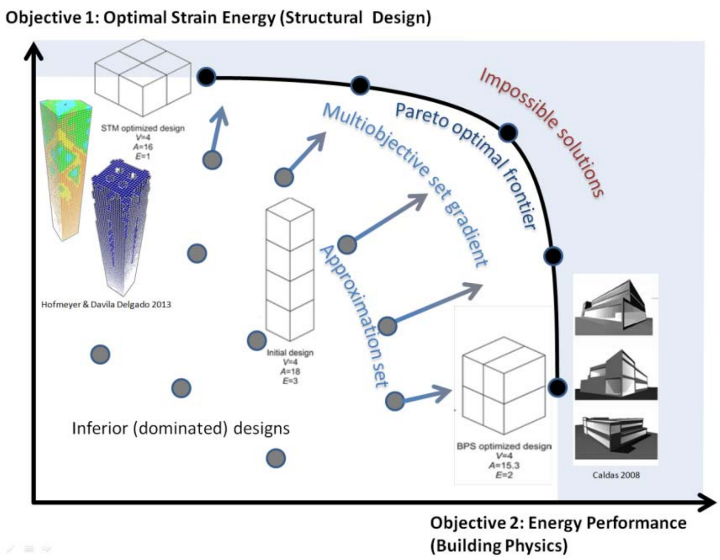
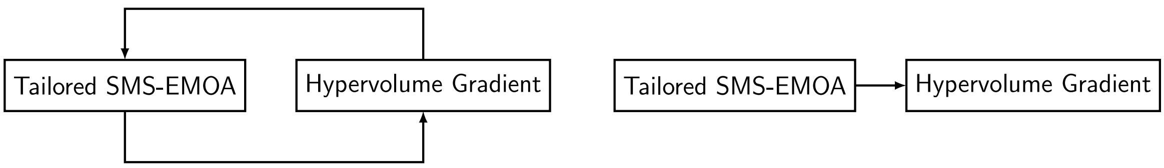


Figure 1: Memetic building spatial design optimisation.

With the operators from [2] it is possible to efficiently navigate the discrete subspace from the mixed integer representation proposed in [1]. Exploring the continuous subspace is however still suboptimal. Here a memetic algorithm is proposed to optimise a building spatial design, as shown in Figure 1, while

considering both subspaces. This memetic algorithm consists of a hybridisation of the tailored SMS-EMOA from [2] and the hypervolume gradient as described in [3].
There are multiple ways to consider the tailored SMS-EMOA and the hypervolume gradient in hybrid. Figure 2 shows two possible strategies. Hybridisation by alternation allows the hypervolume gradient to be applied to every (non-dominated) point in the discrete subspace that is considered. When the two optimisers are used in relay (as considered in [4]) the tailored SMS-EMOA can first search through the mixed integer space for a good Pareto front approximation, after which the hypervolume gradient can steer the population towards the exact local Pareto front of the continuous subspace.



(a) Alternate (b) Relay

Figure 2: Two hybridisation strategies.

In this work the hypervolume gradient is applied in a real design environment for the first time. The pros and cons of the different hybridisation strategies for the problem of building spatial design optimisation are weighed against each other. In addition, a number of challenges with the use of gradients specific (but not exclusive) to this problem are tackled. For instance, the continuous variables are bounded by box constraints, which requires the gradients of points at these boundaries to be handled differently. Moreover, during optimisation the volume of the building spatial design is kept constant by rescaling the continuous variables. This manipulation of the continuous variables poses a challenge to finding accurate gradient information.

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