Local Active Subspaces for Constrained Global Aerodynamic Shape Optimisation

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Abstract. This talk focuses on the development of an efficient algorithm for high-dimensional, constrained, surrogate-based optimisation of complex engineering design problems. The work bridges the gap between gradient-based and global optimisation methods, being robust to both dimensionality and multimodality or non-stationarity of the objective function. A specificity of the work is the use of adjoint-based gradient information throughout. Our contributions are two-fold:

First, we enhance linear, gradient-based active subspaces by pairing them with an unsupervised clustering algorithm, to form tailored piecewise-linear local dimension reduction. We complement this strategy with a novel, boundary-aware overlapping scheme to increase surrogate model accuracy across cluster interfaces.

Our second contribution enables dimension-reduced Bayesian optimisation by answering four practical questions: (i) Where to maximise the acquisition function? (ii) How to maximise the acquisition function? (iii) How to map back to the design space? (iv) How to manage constraints?

(i) Where to maximise the acquisition function?
We alleviate the curse of dimensionality for the estimation of the reduced-space feasible set, enabling tight approximations of high-dimensional zonotopes.

(ii) How to maximise the acquisition function?
We employ a two-stage, boundary-aware global search followed by a polishing step that efficiently and reliably selects feasible candidates.

(iii) How to map back to the design space?
Feasible-set estimates guarantee admissible pre-images, enabling simpler inverse mapping.

(iv) How to manage constraints?
We present several ways to integrate dimension-reduced constraint surrogates to handle non-linear engineering constraints within the Bayesian optimisation loop.

These questions were answered with the goal of benchmarking the method on analytical test cases up to 100 design variables, before a demonstration on an industrially-relevant aerodynamic shape optimisation problem.

References

1. M. Chapron et al. (2025) *Clustered Active Subspaces for Aerodynamic Shape Optimization*. AIAA SCITECH 2025 Forum, Orlando, FL. doi:10.2514/6.2025-0652.