On-the-fly Multi-fidelity Reduced Order Modeling on Large-scale Topology Optimization

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Abstract: Large-scale structural topology optimization has always suffered from prohibitively high computational costs that have till date hindered its widespread use in industrial design. The first and major contributor to this problem is the cost of solving the Finite Element equations during each iteration of the optimization loop. This is compounded by the frequently very fine 3D models needed to accurately simulate mechanical or multi-physical performance. The second issue stems from the requirement to embed the high-fidelity simulation within the iterative design procedure in order to obtain the optimal design. The prohibitive number of calculations needed as a result of both these issues, is often beyond the capacities of existing industrial computers and software. To alleviate these issues, we will develop an innovative methodology in the combined fields of Reduced-Order Modeling and Topological Optimization. The key idea consists in projecting the high-dimensional system of equations into a low-dimensional space, with reduced basis vectors built by Multi-Fidelity Proper Orthogonal Decomposition. These vectors will be updated with incremental "on-the-fly" merges between costly high-fidelity simulation snapshots and more rapid lower-fidelity ones (multi-fidelity). The core contributions involve the development of relevant criteria to determine the required levels of precision, transfer operators between different levels, the optimal size of the reduced basis, and the frequency of the basis reconstruction. The sensitivity analysis will also be studied in this context. Finally, the tests on 2D and 3D benchmark problems demonstrate improved performance with acceptable objective and constraint violation errors. Successful achievements of this work will lead to potential benefits in the fields of large-scale mechanical engineering.