論文の要旨

題目: Improved methodologies for efficient aerodynamic shape optimization of a realistic vehicle with "noisy" computations

(「ノイズ」を含んだ数値解析による実車両の効率的空力形状最適化手法の改良)

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To achieve the maximum possible improvement in expensive optimization problems with "noisy" computations, such as the drag reduction of a realistic vehicle, within a short period of time, an optimization system is proposed. This system combines the regression Kriging with re-interpolation (RKri) surrogate technique and pseudo expected improvement (PEI) criterion-based efficient global optimization (EGO) algorithm (EGO-PEI), thereby called RKri-EGO-PEI. This is then applied to filter out all kinds of noise produced by computational fluid dynamics (CFD) simulations, maintain a smooth functional trend of the surrogate model, and carry out point infills in a parallel manner in a real-world expensive optimization problem. Additionally, the initial samples with high space-filling quality are also beneficial to further reducing a total number of samples required. To employ a limited number of samples to represent a continuous design space, two modified algorithms, namely, the modified enhanced stochastic evolutionary (MESE) and translational propagation MESE (TPMESE) algorithms, are proposed to construct optimal Latin-hypercube designs (OLHDs) efficiently. The proposed algorithms and each of their original algorithms are applied to compare with other state-of-the-art heuristic algorithms using optimization tests with different-size LHDs. The results show that the TPMESE and MESE converge faster not only than other competitive algorithms but also than each of their original algorithms, respectively. To guarantee two critical optimization processes of tunning Kriging hyperparameters and searching for the optimum on the PEI function, the performance advantages of optimizers on the EGO-PEI algorithm are then investigated. Subsequently, the best one in the benchmark tests is chosen as the optimizer in the proposed optimization system. To confirm the performance of the RKri-EGO-PEI system, two existing optimization systems, namely ordinary Kriging-based EGO-PEI (OK-EGO-PEI) and RKri-based EGO (RKri-EGO), are employed to compete with the proposed system in minimizing the drag coefficient (Cd) of a realistic vehicle using CFD simulations. Furthermore, an object-oriented optimization toolbox, namely, vehicular aerodynamic engineering optimization (VAEO), is programmed to guarantee the smooth implementations of all optimization processes. The results of optimizer tests reveal that an optimizer with higher central goal of exploitation-exploration can not only promote better convergence of the EGO-PEI algorithm within a certain number of point infills, but also achieve the same-level convergence of the EGO-PEI algorithm as that using the other optimizers, with fewer iterations. Regarding the real-world application, the results show that the RKri-EGO-PEI converges to a lower Cd of the vehicle model than those of the OK-EGO-PEI and RKri-EGO systems, with a smaller wall-clock time cost.