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Kriging-Based Global Optimization Method for Bluff Body Drag Reduction

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Abstract : We propose a Kriging-based global optimization method for active flow control with multiple actuation parameters. This method is designed to converge quickly and avoid getting trapped into local minima. We follow the model-free explorative gradient method (EGM) to alternate between explorative and exploitive steps. This facilitates a convergence similar to a gradient-based method and the parallel exploration of potentially better minima. In contrast to EGM, both kinds of steps are performed with Kriging surrogate model from the available data. The explorative step maximizes the expected improvement, i.e., favors regions of large uncertainty. The exploitive step identifies the best location of the cost function from the Kriging surrogate model for a subsequent weight-biased linear-gradient descent search method. To verify the effectiveness and robustness of the improved Kriging-based optimization method, we have examined several comparative test problems of varying dimensions with limited evaluation budgets. The results show that the proposed algorithm significantly outperforms some model-free optimization algorithms like genetic algorithm and differential evolution algorithm with a quicker convergence for a given budget. We have also performed direct numerical simulations of the fluidic pinball (N. Deng et al. 2020 J. Fluid Mech.) on three circular cylinders in equilateral-triangular arrangement immersed in an incoming flow at Re=100. The optimal cylinder rotations lead to 44.0% net drag power saving with 85.8% drag reduction and 41.8% actuation power. The optimal results for active flow control based on this configuration have achieved boat-tailing mechanism by employing Coanda forcing and wake stabilization by delaying separation and minimizing the wake region.

Keywords : direct numerical simulations, flow control, kriging, stochastic optimization, wake stabilization
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