11th World Congress on Structural and Multidisciplinary Optimisation
07th -12th, June 2015, Sydney Australia

Efficient Aerodynamic Optimization Using a Multiobjective Optimization Based Framework to Balance the Exploration and Exploitation

Zhiwei Feng[1], Tao Yang[1], Jianquan Ge[1], Qiangang Tang[1], Yang Ma[1]

[1] National University of Defense Technology, Changsha, China, fzwnudt@nudt.edu.cn

Abstract

In the optimization design of aerodynamic shape of a flight vehicle or airfoil, the objective function evaluation is done via high-fidelity and expensive computational fluid dynamics (CFD) simulation. In spite of great development of computing technology, such as the more accurate and faster simulation code and parallel computing, the efficient optimization method is still an open research area. Modern heuristics are not suitable since these methods often require an unbearable number of function evaluations.

Due to the importance of expensive optimization, much effort has been made for developing methods to produce a reasonably good solution within a given budget on computational cost or time. A widely used approach for dealing with expensive optimization utilizing high-fidelity analysis is to use cheap global surrogate (approximation) models to substitute expensive simulation. Kriging is have been widely applied to many expensive optimization problems, since it can approximate nonlinear and multi-modal functions, and produce unbiased prediction at untested points. Actually, Kriging has been. Efficient Global Optimization (EGO) is the most popular Kriging based expensive optimization method [1].

The infill sample selection criterion is an important issue for Kriging based optimization, such as EGO. In the original EGO or several aerodynamic optimization problems, one test points for evaluation is determined at each iteration. To make good use of parallel computing resources, a multiobjective optimization based framework has been proposed to balance the exploration and exploitation for expensive optimization problem, called EGO-MO [11]. It treats balancing the local exploitation and global exploration as a multiobjective optimization problem (MOP). Then, a multiobjective optimization algorithm can be used for obtaining the Pareto set, i.e., a set of best trade-off solutions for balancing exploitation and exploration. Several points can be selected from the Pareto set for evaluation in a parallel manner. In such a way, parallel computing techniques can be used for reducing the clock time for optimization. Additionally, the Multiobjective Evolutionary Algorithm based on Decomposition (MOEA/D) [3] is employed to solve the aforementioned MOP. Due to the population nature of MOEA/D, it is able to escape from local optimal solutions and give a set of high quality trade-off candidates for local exploitation and global exploration.

In the airfoil shape optimization problem, the objective is to minimize drag maintaining the reference lift for the transonic airfoil rae2822. The class/shape transformation (CST) [4] function is employed for the parameterization of the airfoil. The open source code SU^2 [5] is adopted to perform the high-fidelity aerodynamic analysis of initial and infill sampling points. The EGO-MO and standard EGO is applied to solve the aforementioned airfoil optimization problem. The optimum results are analyzed for the mechanism of the drag reduction. The two methods are compared for the function evaluation number and the iteration number. The investigation shows that the EGO-MO feature less iteration numbers than standard EGO and can give better optimal results.

References

[1] D. R. Jones, M. Schonlau, W. J. Welch. Efficient global optimization of expensive black-box functions [J]. Journal of Global Optimization, 13: 455-92, 1998.

[2] Z. Feng, Q. Zhang, Q. Zhang, et al. A multiobjective optimization based framework to balance the global exploration and local exploitation in expensive optimization [J]. Journal of Global Optimization, 61(4): 677-94, 2015.

[3] Q. Zhang, H. Li. MOEA/D: a multiobjective evolutionary algorithm based on decomposition [J]. IEEE Transactions on Evolutionary Computation, 11: 712-31, 2007.

[4] B. M. Kulfan. Universal Parametric Geometry Representation Method [J]. Journal of Aircraft, 45(1): 142-58, 2008.

[5] F. Palacios, M. R. Colonno, A. C. Aranake, et al. Stanford University Unstructured (SU2): An open-source integrated computational environment for multi-physics simulation and design [C]. Grapevine , Texas: 51st AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition, 2013.