IMPROVING THE EVOLUTIONARY AERODYNAMIC OPTIMIZATION WITH BEZIER-PARSEC PARAMETERIZATION USING POPULATION SIZE REDUCTION METHODS

Quijada Pioquinto J.G., Shakhov V.G.
Samara National Research University, Samara, hosekihada@yandex.ru

Keywords: parameterization Bezier-PARSEC, shape optimization, SHADE algorithm, population size reduction methods.

In 2004, Rogalsky proposed the new Bezier-PARSEC (BP) parameterization method for airfoils [1]. This new method aims to accelerate the convergence of evolutionary aerodynamic optimization processes. To achieve this task, the new method proposes a reduction in nonlinear interactions between design parameters, which leads to a reduction in the space of design variables [2]. Rogalsky and Derksen proved the abilities to represent subsonic airfoils with BP parameters. These tests were performed with the differential evolution (DE) algorithm with the variant DE/rand-to-best/1, and the objective function was the geometric deviation measured by the L2-error norm [3, 4]. The tests consisted of defining an optimal value of the target function and determining the number evaluations of the target function that was required to reach the goal, this process was performed with 63 different airfoils. The results were satisfactory, showing that one could have a small number of design variables (which implies a smaller number of individuals per generation), which accelerates the optimization process without the need to risk the globality of the search for the optimal value [1, 2, 3]. Rogalsky and Derksen developed two variants of BP parameters based on the degree of the polynomial of the Bezier curves used, the parameters BP3333 (with 4 third-degree curves and 12 variables) and the parameters BP3434 (with 2 third-degree curves and 2 fourth-degree curves and 15 variables) [1, 3]. In this work only the BP3333 variant was evaluated, see Fig. 1.

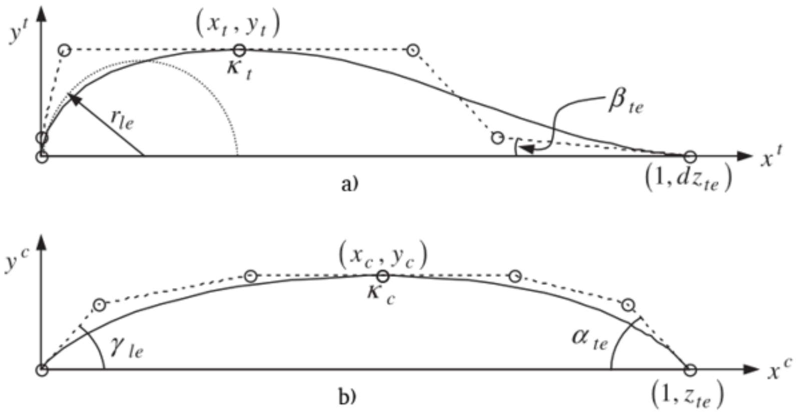

Fig. 1 – Parameters BP3333 and Bezier control points: a – thickness curve, b – camber curve [3]

This work provides a new proposal to further accelerate the process of evolutionary optimization through population size reduction (PSR) methods. It is also proposed to use the Success-History based Adaptive DE (SHADE) algorithm. Success-history based adaptation is a mechanism for parameter adaptation based on a historical memory of successful parameter settings that were previously used found during the run [5]. The SHADE algorithm is used for the adaptability of incorporating PSR methods: linear reduction (L-PSR) [6], exponential reduction (E-PSR) [7], parabolic reduction (P-PSR) [8] or nonlinear reduction (NL-PSR) [9].

To test the effectiveness of the SHADE algorithm with the PSR variants, representation tests were performed on 34 airfoils (extracted from the UIUC Airfoil Data Site [10]), and the number of target functions evaluated to achieve the optimal value established with the algorithm used by Rogalsky and Derksen were compared. As in the Rogalsky and Derksen tests, the target function is the geometric deviation, and having as the stopping condition a value of 0.01. Each case was tested 51 times. The SHADE E-PSR algorithm proved to have the best convergence rate, being best in 26 out of 36 cases. The algorithm proposed by Rogalsky and Derksen was only faster in 2 cases, but the difference was not very noticeable. Overall, the SHADE E-PSR algorithm required fewer evaluated functions than the original algorithm, achieving a difference of approximately 1200 evaluated functions.

This amount of saved functions is considerable when performing high fidelity reverse aerodynamic design processes, where the target functions to be evaluated are the Navier-Stokes equations. This implies fewer individuals evaluated, less computation time, and provides a certainty of finding an overall optimal value.

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Information about the authors

Quijada Pioquinto Jose Gabriel, Master of Science, PhD student. Field of scientific interests: aerodynamic shape optimization.

Shakhov Valentin Gabrielovich, proffesor. Field of scientific interests: mechanics of fluids.