APPLICATIONS OF EVOLUTION STRATEGIES

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Abstract

Evolution strategies are one of the main paradigms in the field of *evolutionary computation*, focusing on algorithms for adaptation and optimization which are gleaned from the model of organic evolution.

The excellent global optimization properties of evolution strategies are demonstrated in the studies by Schwefel by using a test suite of more than 50 objective functions [157, 158]. These are artificial test functions, however, such that one might be tempted to ask for practical applications of the evolution strategy.

In this report, relevant practical applications as reported in the literature are summarized to provide the reader with an overview of the capabilities of these powerful algorithms. In the first section one application from the field of *computational fluid dynamics (CFD)* is described in detail. This field provides a wide range of hard optimization tasks where several optimization techniques have been tried to achieve reasonable results. The application of evolutionary algorithms promises improved results in comparison to the ones from standard techniques, e.g. hill climbers and gradient based methods.

In second section a catalog of different applications is given. These application case studies cover a wide range of disciplines, including artificial intelligence, biotechnology, technical design, chemical engineering, telecommunications, medicine, microelectronics, military, physics, robotics, production planning, and others. All this applications could have been described more detailed like the one before, but this layout seems more reasonable to the authors to convince the reader of the effectiveness of applying evolutionary algorithms to their own problems.

1 AIRFOIL DESIGN

The two-point airfoil design problem - originally proposed by T. Labrujere from NLR [114] - is defined by the minimization of an objective function being the difference between the computed pressure coefficient at two different design points and pre-defined target pressures.

In order to check carefully the accuracy of the optimization process in general, one or two initial test cases can be run prior to the multi-point case, e.g. the pressure re-design case of either the subsonic or transonic flow. The single-objective case enables the optimizer to have faster results for different variants of evolutionary algorithms while otherwise being able to compare the results achieved with the ones obtained so far.

The objective function for the discussed transonic redesign case reads:

$$F(s) = W \int_0^1 (C_p(s) - C_{p,target}(s))^2 ds \quad (1)$$

with s being the airfoil arc-length measured around the airfoil and W a weighting factor. C_p is the pressure coefficient distribution of the current and $C_{p,target}$ the pressure coefficient distribution of the target airfoil, respectively.

1.1 Test-case environment

Surface data for both airfoils, the transonic low-drag and subsonic high-lift airfoil, are prescribed. All data sets needed for validation purposes can be provided by W.Haase from DaimlerChrysler Aerospace[1] or directly accessed from the INGENET Web site[2]. These data are accompanied by target pressure data computed using a Navier-Stokes approach.

It was mentioned already that the multi-point design case uses a sophisticated CFD method as an analysis tool, in particular a 2D Navier-Stokes approach. No particular attention is payed to the problem of flow-physics modeling. The turbulence models applied for the present cases are the Johnson-King model for subsonic flow (a model with clear capabilities to predict pressure induced separation) and the Johnson Coakley model for transonic flow, respectively. These models have been chosen because of their predictive accuracies to accurately describe all non-equilibrium flow physics phenomena in the desired flow regimes, compare [38].

The parameterization [168] used for the airfoil investigations is based on Bezier splines for the upper and lower airfoil surface, respectively. In total, 6 or 12 Bezier "weighting points" have been chosen as design parameters, the individuals for the evolutionary algorithm contain the y-components of these Bezier points. A parameterization obviously leading

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