# OPTIMAL DESIGN OF AEROFOIL SYSTEMS FOR MANY CRITERIA

T. Schlieter[1] and A. Długosz[2]

[1, 2]*Institute of Computational Mechanics and Engineering*
*Faculty of Mechanical Engineering*
*Silesian University of Technology, Gliwice, Poland*
*e-mail: [1]tomasz.schlieter@polsl.pl, [2]adam.dlugosz@polsl.pl*

## 1. Introduction

The problem of optimal design of mechanical systems for more than 3 criteria attract more and more attention in the recent years. Such problems require efficient optimization algorithms as multiple numerical computation of objective functions for the mechanical problems is often extremely time consuming. The aim of this research is to develop an algorithm with improved convergence for a large number of criteria, employing an idea to couple game theory elements with differential evolution algorithm. Game theory elements are used to compare solutions, each player to represent a single objective. Differential Evolution is a population based evolutionary optimizer which in many variants found application in a range of engineering and scientific problems. The developed, coupled algorithm can be be useful in a wide range of real world multiobjective problems, including optimization of composite, thermoelastic, electrostatic and piezoelectric structures. Aerofoil design optimization problem was presented as a numerical example of application of designed algorithm in mechanical systems and finited element method software was used to determine values of objectives considered during the course of optimization.

## 2. Differential Evolution

Differential Evolution (DE) as a single objective optimizer was introduced by Price and Storn in 1997 [1] and is acclaimed for its simple structure, ease of use, speed and robustness. The algorithm utilises selection and mutation as exploration and exploitation mechanisms. Initial population is a set of parameter vectors usually chosen randomly from the solution space. During the course of optimization a weighted difference between two population members is calculated and then added to a third one to create a new design variables vector. If the resulting vector yields an improved objective value it replaces the former one.

## 3. Elements of game theory

In the multiobjective optimization problems a set of Pareto optimal (non-dominated) solutions is searched. The idea behind coupling DE and elements of game theory comes down to treating objectives as players, playing a cooperative game, trying to improve their respective objectives with the resources given and sharing the information with each other, iteratively looking for a Nash equilibrium. Each player is given a part of design variable vector at random as their resources, while the rest of the vector is fixed and determined by other players' choices. To assure diversification of solutions after each player makes his move, using a single objective DE optimizer to find a proposed solution, the assignment of resources is changed in a way each design variable is modified by one and only one player. Such an approach is used instead of traditional comparison methods based on dominance rank, depth or count, which encounter difficulties when solving tasks with more criteria since there is too many non-dominated solutions which can't be effectively compared.


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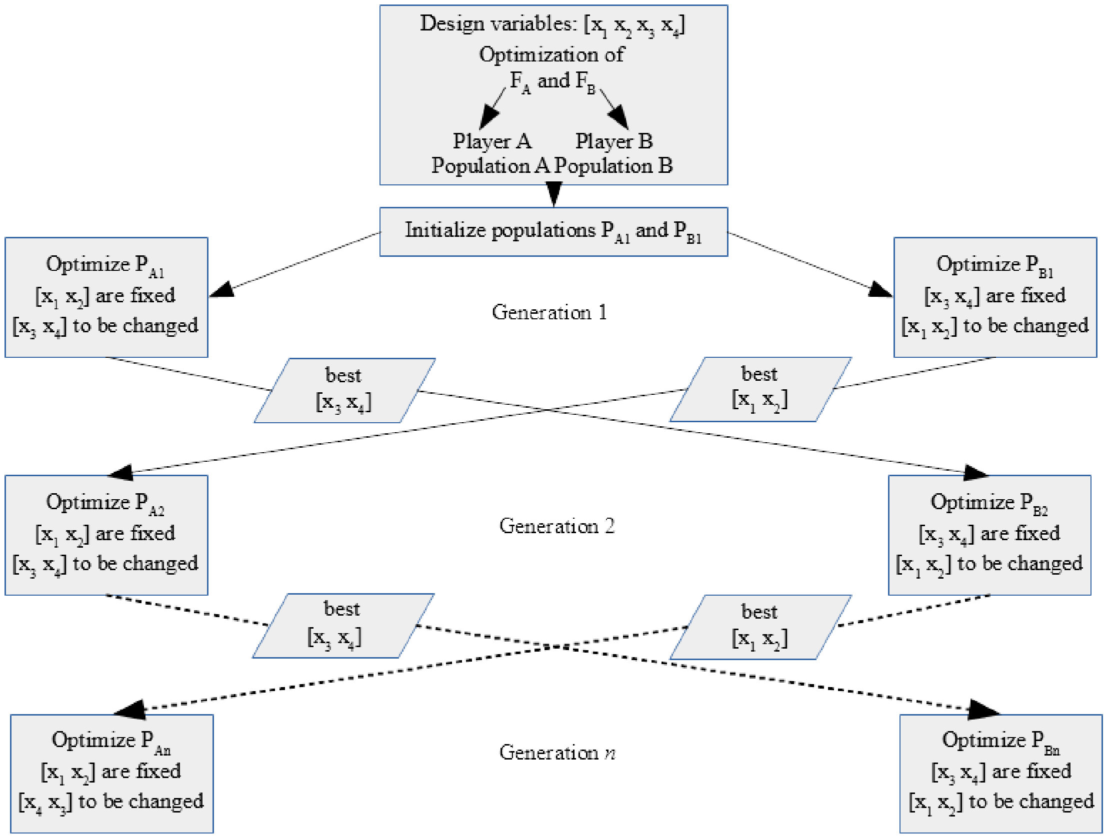


Figure 1: Coupled differential evolution and game theory multiobjective optimization algorithm.

## 4. Aerofoil design

Aerofoil systems are used to develop an aerodynamic force when moving through the fluids. When designing the optimal shape of an aerofoil many contradictory criteria have to be taken into consideration to provide the system with the desired properties, such as high endurance, low weight and high lifting force. Considered Aerofoil design consists of polyurethane foam and composite materials reinforced with carbon and glass fabric.

## 5. Objectives and design variables

Objectives in the optimization problem are devoted to minimization of maximal equivalent stresses, minimization of maximal displacements, minimization of total mass of the model and maximization of difference between values of modal frequency of a system and a given frequency – these are the examples of conditions required of aerofoil systems, although other criteria based on specific needs can be formulated. Values of functionals used as objectives are computed using FEM simulations. Boundary conditions and material properties are fixed during the optimization course and geometry of the model, described by design variables is changed to fit the declared needs, formally described by aforementioned functionals.

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**References**

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