Differential evolution and elements of game theory for multi-objective optimization in mechanics

Adam Długosz and Tomasz Schlieter

Silesian University of Technology, Poland

The problem of optimal design of mechanical systems for more than 3 criteria attract more and more attention in recent years. Such problems require efficient optimization algorithms as multiple numerical computations of objective functions for the mechanical problems are often extremely time-consuming and effective optimization methods have to be applied. In this research a novel algorithm was developed with improved convergence for a large number of criteria, employing an idea to couple game theory elements with a 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 proposed algorithm is based on differential evolution and game theory paradigms. The suggested algorithm takes advantage of a game-theoretic cooperative approach and eliminates some drawbacks of other soft computing methods in the optimization of mechanical systems. The developed algorithm can be useful in a wide range of real-world multiobjective problems. The algorithm is comprehensively tested using introduced benchmark functions and performance metrics with comparison to other popular multi-objective optimization algorithms, such as NSGA-II and NSGA-III. A set of mathematical test functions exhibiting features distinctive of mechanical systems is utilized. The quality of results is assessed using a hypervolume indicator. Numerical examples of multi-objective optimization of selected mechanical systems are included. Functionals that represent real requirements asked of mechanical systems are proposed, formulated and numerically implemented. The boundary-value problem of a mechanical field was solved multiple times during optimization by way of the finite element method (FEM). Another important aspect is the representation of the multi-dimensional Pareto front and the selection of the interesting solutions when a large number of criteria is considered. The alternative method, compared to the traditional one, concerning the representation and selection compromise solutions, is proposed. The proposed method is aided by self-organizing maps (SOMs), which is one type of artificial neural network (ANN). Based on additional established preferences and using proposed visualization tools, a post-optimization decision-making process was aided resulting in a narrowed down set of solutions.

Funding Acknowledgment: The research was partially funded from financial resources from the statutory subsidy of the Faculty of Mechanical Engineering, Silesian University of Technology.