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OPTIMAL DESIGN OF MECHANICAL SYSTEMS FOR MULTIPLE CRITERIA BY MEANS OF SOFT COMPUTING METHODS

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ABSTRACT

The dissertation investigates the subject of optimal design of mechanical systems for many criteria. In the literature review basic information on the process of design are presented with special attention given to the optimization tasks. Overview of finite element method as a simulation tool from the perspective of optimization of mechanical systems is included. Metrics and benchmark functions are reviewed in the context of evaluating performance of multiobjective optimization algorithms. Visualisation techniques enhancing post-optimization decision making process are described.

Next part of the dissertation presents developed multiobjective optimization algorithm belonging to a group of soft computing methods. Proposed algorithm is based on a differential evolution and game theory paradigms. Suggested algorithm takes advantage of a game theoretic cooperative approach and eliminates some of drawbacks of other soft computing methods in the optimization of mechanical systems. Elements of game theory are introduced along with basics of differential evolution. General idea a novel multiobjective algorithm is described and presented using a flowchart, a pseudocode and supplemented with an example. Implementation of the algorithm in C++ programming language is briefly described. Methods of information exchange between developed algorithm and FEM software responsible for numerically obtaining values of objective functions during the course of optimization are discussed.

In the subsequent part of the dissertation, the algorithm is comprehensively tested using previously introduced benchmark functions and performance metrics. A set of mathematical test functions exhibiting features distinctive of mechanical systems is utilised. Quality of results is assessed using a hypervolume indicator. Mean and standard deviation of metrics are calculated over 30 runs of algorithm and compared with results obtained by other multiobjective optimization algorithms: NSGA-II and NSGA-III. Test problems with a varied number of design variables (up to 20) and objective functions (up to 8) are investigated. Within analysed framework the developed algorithm was proven to be efficient and competitive with compared algorithms.

Ensuing part of the dissertation provides examples on application of the developed tool in the optimal design of mechanical systems. A set of three analytical problems: pressure vessel design, speed reducer design and stepped cantilever beam are examined. These analytical problems are produced by a transformation of constrained single-objective optimization problems into multiobjective problems. Furthermore, the algorithm is used to solve complex, numerical problems: airfoil optimization, electrothermal microactuators optimization and multiscale porous material optimization. In these problems, values of objective function are obtained by means of FEM based on parametric models. For each of analysed problems, algorithm found a set of new diverse designs. Results were presented in the form of tables, graphs, and figures. On the basis of additional established preferences and using proposed visualisation tools, a post-optimization decision making process was aided resulting in a narrowed down set of solutions.