ON DEDICATED EVOLUTIONARY ALGORITHMS FOR LARGE
NON-LINEAR CONSTRAINED OPTIMIZATION PROBLEMS
IN APPLICATION TO RESIDUAL STRESSES ANALYSIS

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This work considers development of dedicated Evolutionary Algorithms (EA) with several specialized acceleration techniques introduced. Many scientific and engineering tasks may be formulated as optimization problems, and require efficient solution methods. Therefore, our long-term research [2] is oriented towards development of such methods for a wide class of large, non-linear, constrained optimization problems, where a discrete function is sought, e.g. expressed in terms of its nodal values. These values are defined on a mesh formed by arbitrarily distributed nodes. We are presenting here a preliminary application of the improved EA to residual stresses analysis. The final objective of our research is such analysis performed for railroad rails, and vehicle wheels, because tensile residual stresses are of great importance for reliable prediction of rail and wheel service life resulting from its fatigue failure [3,4]. Both theoretical and experimental investigations of residual stresses may be expressed in terms of large, non-linear, constrained optimization problems [4]. Experimental approach may use the Physically Based Approximation (PBA) [4]. In contrast to most of deterministic methods, the EA may be successfully applied to both the convex and non-convex problems, however, their general efficiency is rather low. Due to the size and complexity of the optimization problems in question, our research is focused, first of all, on the efficiency increase of the EA.

The EA are precisely understood here as decimal-coded Genetic Algorithms consisting of three basic operators: selection, crossover and mutation [1]. Acceleration of the solution process may be achieved in various ways [1] including e.g., development of new, problem-oriented operators, hybrid algorithms, standard parallelization of computations. Moreover, we have recently proposed, and preliminarily tested, several efficient acceleration techniques based on chosen simple concepts [2]. These techniques include: smoothing and balancing of results, solution averaging, as well as the use of a posteriori error analysis [5], adaptive step-by-step mesh refinement, non-standard parallel and distributed calculations [5], and possible combinations of the above [2]. We are presenting here the state of the art and recent advances in our research.

The EA acceleration techniques mentioned above may be used separately, or may be combined together. We have proposed a solution approach based on adaptively refined series of meshes, using simultaneously a posteriori error estimation, and smoothing of raw results. The basic concept of such step-by-step mesh refinement is to start analysis from a coarse mesh, where an approximate solution is obtained much faster than in the fully dense case. Such mesh is refined next by inserting new nodes, based on the results of the error analysis. The initial
function values at these nodes are found by using an appropriate approximation, e.g. the Moving Weighted Least Squares (MWLS) technique, applied to the coarse mesh nodal values. Such process is repeated until a sufficiently dense mesh is reached. Furthermore, mesh refinement is also used for initial reference solutions generation in the a`posteriori error analysis. Generation of reference solutions is based on the stochastic nature of the EA. It is done by a weighted averaging of the best chromosomes taken from independent populations [5]. Knowledge about errors is used by appropriately modified operators to intensify calculations in large error zones.

Several benchmark problems were chosen in order to evaluate the efficiency of the proposed acceleration techniques. In particular, we have analyzed residual stresses in an elastic-perfectly plastic bar subject to a cyclic bending, and in the thick-walled cylinder made of the same material subject to cyclic loadings, like internal pressure, torsion and tension. These problems were analyzed in 1D (taking into account all symmetries), and in 2D as well. We have also analyzed sample inverse problems of reconstruction of residual stresses using simulated pseudo-measurements and the PBA approach. Preliminary results of the executed tests clearly show a significant improvement of the optimization process in comparison with the standard EA. So far we have obtained the speed-up of about 120 times. It is also worth noticing, that the improved EA allowed obtaining solutions in cases when the standard EA failed, e.g. for a large number of decision variables. Typical results are shown in Fig. 1. Present are results of residual stresses obtained from the pressurized cylinder 1D analysis. They were obtained by the improved EA using a series of meshes and a`posteriori error analysis. The process started with 7 nodes, and was continued until the number of 3073 nodes was reached.

![Figure 1: Solutions in the cross-section obtained for initial subsequent meshes with 7, 13, 25, 49 nodes respectively (a-d) and final 3073 nodes (e)](image)

Preliminary results of the executed tests and comparisons with solutions obtained by the Meshless Finite Difference Method are very encouraging. Future research includes continuation of various efforts oriented towards improvement of the EA-based approach, analysis of further benchmark problems, and application of developed methods to residual stresses analysis in real engineering problems, e.g., railroad rails and vehicle wheels [4].

REFERENCES