INCORPORATING TWO OPTIMIZATION ALGORITHMS INTO FEA ENVIRONMENT

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1. General

Genetic algorithms (GA) have become a popular approach in designe optimization in engineering applications in recent years. GAs base on the rule of the survival of fittest in natural selection. Improvement of global search can be done by employing in optimization procedure of neural networks (NN) which can learn and adapt changes over the time.

In the paper the design optimization with the use of FEA and both genetic algorithms and neural network approaches is discussed. The prepared software tool bases on existing open source libraries, namely Galileo for GA, and ffnet for NN. FE modeling, analysis and post-processing were carried out with the use of Abaqus Unified FEA suite. The optimization procedure was implemented with the use of Python (objective programming language) and the Abaqus Scripting Interface.

2. First approach - optimization using FEA and GA

The first presented approach of optimization is based on GA only. Evaluation of each individual bases on the results of FE analysis using Abaqus. The chromosomes created during genetic process constitute the starting point for evaluation procedure. For each chromosome, FE model is created and simulation is performed. The obtained results are interpreted according to a given objective function. The flow-chart of the applied algorithm is presented in Figure 1. The described approach is general one. Any nonlinear static as well as dynamic FE simulation can be used for evaluation procedure. Unfortunately, GAs are in general computationally expensive. Moreover, a random character of GAs requires a multiple usage of optimization procedure. As a result of above, this approach requires efficient and robust methods and resources and it is not used for large design optimization problems.

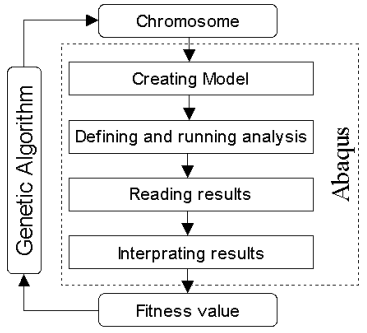

Figure 1. Chromosome evaluation using Abaqus

3. Second approach - optimization using FEA, GA and NN

The base of modification of the described above method is an assumption that GA does not demand a precise solution for each chromosome. The crucial task of evaluation mechanism is extracting features of a chromosome which improve the quality of the individual. Thus, it is

recommended to use an estimation tool which can rate the fitness less accurately but faster.

In the second presented approach of optimization it is proposed to replace the evaluation based on FE analysis with an estimation based on NN. In order to train NN, numerical analysis results for the selected and randomly generated chromosomes are used as a training set. When the learning process is terminated, an optimization attempt is carried out with the use of GA. This step corresponds to the first presented idea of optimization process with one exception; the evaluation procedure is done now with the use of NN. For each iteration of an optimization loop a training set is updated. A new training data consists of the result for the best individual obtained using GA and additionally, in the case of parallel computations, either results for random chromosomes or for created as a result of the best chromosome mutation. New training data verifies the GA solution in the first place and increases space of NN approximation on the other hand. As a result, the next GA optimal solution is calculated taking into consideration all previous attempts. The architecture of NN is changing simultaneously with the optimization process. The well-fitted architecture of NN is calculated according to a learning error. Each expensive FE analysis is used for improving an estimation tool – NN. The greater number of analyses, the better estimation of individual is expected, however, in many cases NN is able to detect advantageous features even in a small number of training data. A flow-chart of the algorithm described above is presented in Figure 2.

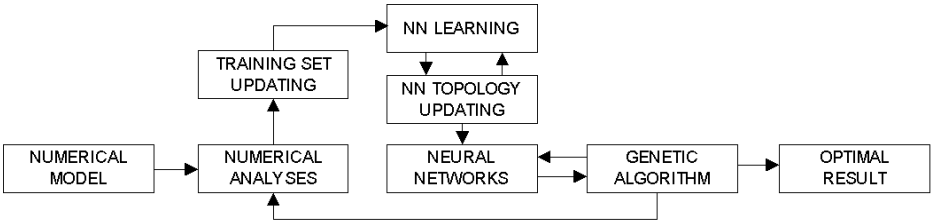

Figure 2. Flow-chart of modified optimization procedure.

4. Examples

The presented algorithms were tested and verified for several problems. The general character of GA optimization method enables us to use it in cases of a wide range of engineering applications. At the beginning very simple linear problems e.g. spanned beam with a uniformly distributed load was considered. Next, optimization of more complex nonlinear structures such as screw connection and skin-stringer structure were carried out.

5. References

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