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SOFTCOMPUTING METHODS BASED IDENTIFICATION OF NONLINEAR MECHANICAL MODEL PARAMETERS

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ABSTRACT

The problem of inverse analysis occurs in many engineering tasks and, as such, attains several different forms and can be solved by a variety of very distinct methods. This contribution presents an overview of two basic philosophies of the inverse analysis aimed, in particular at estimation of mechanical model parameters. When new numerical model is developed, the identification process is necessary for validating of proposed model to fit the experimental data. This process become a challenge especially in cases of complex nonlinear numerical models applied to simulate an experiment on structures undergoing the heterogeneous stress field such as three-point bending test or nano-indentation, or when dealing e.g. with optimal design or optimal control of structures with nonlinear behavior.

In overall, there are two main philosophies to solution of identification problem. A forward (classical) mode/direction is based on the definition of an error function of the difference between outputs of the model and experimental measurements. A solution comes with the minimum of this function. This mode of identification could be considered as more general and robust and therefore, it is usually applied in numerical model validation. The second philosophy, an inverse mode, assumes the existence of an inverse relationship between outputs and inputs. If such relationship is established, then the retrieval of desired inputs is a matter of seconds and could be easily executed repeatedly.

Several methods suitable for parameters identification are proposed in [1]. Particularly, two genetic algorithms (the SADE algorithm and the GRADE algorithm) are designed and approved as a very robust and reliable optimization methods usable for forward mode of identification. Their reliability is improved by combination with the proposed niching strategy so-called CERAF. The proposed algorithms were applied to solve twenty mathematical optimization problems. The results have shown that genetic algorithms are very robust and reliable optimization methods capable to solve non-smooth and multimodal problems especially in combination with the CERAF niching strategy. The SADE algorithm was also applied to artificial neural network training and compared with more traditional method of backpropagation. The results have shown that a genetic algorithm clearly outperforms the backpropagation training, mainly because of genetic optimization's higher resistance to fall into local extremes. Two engineering applications of SADE algorithm to optimization of periodic unit cell for unidirectional fiber composite and to optimal design of reinforced concrete beam are published in [2]. An application of GRADE algorithm to optimal design and optimal control of structure undergoing large displacements

and rotations is presented in [3]. The principal disadvantage of genetic algorithms even extended by the niching strategy is, nevertheless, a huge number of objective function evaluations.

If the objective function has only a limited number of local extremes, some meta-model of the function could be constructed and optimized instead of the original objective function in order to reduce the number of time-consuming objective function evaluations. A methodology based on interpolation of the error function by radial basis function network with adaptive refining was compared with the GRADE algorithm extended by CERAF strategy in optimization of a set of mathematical functions. Proposed methodology could be considered as a very efficient optimization method for objective functions with a limited number of local extremes and with small number of variables (< 10). One application to parameters identification of continuum-discrete damage model capable of representing localized failure is presented in [4], were the non-smooth and non-convex functions were successfully optimized.

All previously mentioned methods are optimization methods suitable for forward mode of an inverse analysis. The main feature common for these methods is the necessity to carry out the whole identification process for any new measurements. Only meta-modelling of a computational model leads to the identification methodology, where only a cheap optimization needs to be executed for new measurements and the time-consuming development of the meta-model is performed only once.

The inverse mode of an inverse analysis leads to the development of an inverse model to the mechanical model and it has similar properties as a forward mode based on metamodelling of the computational model. The methodology given for inverse mode of identification is based on several ideas proposed in [5]. Our version comprises the inverse model development represented by the feed-forward neural network trained by the GRADE genetic algorithm; Latin hypercube sampling strategy applied for training samples preparation and stochastic sensitivity analysis used for the choice of appropriate inputs and outputs. Once the inverse model is established, it could be used repeatedly for any new measurement by a simple evaluation of the inverse model. From the implementation point of view, this approach is very simple to use, because only a limited number of simulations by the mechanical model is needed as a first step of a inverse model development and there is no need to link any optimization algorithm to the code of the mechanical model. The application of the proposed methodology on parameters identification of microplane model is presented in [6].

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