Advances in Reliability, Safety and Security

ESREL 2024
Collection of Extended Abstracts

Warm-Start Training Of Artificial Neural Networks In Context Of Polymorphic Uncertainty Quantification

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Keywords: polymorphic uncertainty quantification, artificial neural networks, surrogate models, fuzzy probability-based randomnes

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Within the numerical design of a structure, the evaluation of uncertainty is crucial in order to assess the quality safety of designs. In such design processes, aleatoric and epistemic uncertainties have to be considered, depending on the uncertainty characteristics of the available data base. Aleatoric uncertainty describes observed variability and epistemic uncertainty describes incompleteness and impreciseness of the data base. In many applications both types of uncertainty appear simultaneously. This can be modeled as polymorphic uncertainty (Beer et al., 2013). A major disadvantage of polymorphic uncertainty quantification is the high numerical effort, which is induced by sampling on the basic solution. According to (Schmidt et al., 2018), surrogate models can be applied in the context of polymorphic uncertainty quantification by replacing the stochastic analysis in the calculation of the uncertain response. Artificial Neural Networks (ANN) are commonly incorporated as surrogate models, in order to reduce numerical effort of simulations by replacing complex functional relations. The focus of this contribution lies on the utilization of ANNs as surrogate models of stochastic analyses in polymorphic uncertainty quantifications. In this surrogate application, another aspect is the improvement of ANNs by a warm-start training, if the result of the ANN reveals to be inadequately deviant from the original solution.

Polymorphic uncertainty quantification of a structure is the calculation of uncertain responses of its physical model. In (Götz, 2017), the estimation of uncertain results is performed by evaluating the different parts of the polymorphic uncertainty by their specific analysis schemes. This is visualized in Figure 1. For the propagation of epistemic uncertainties, an α-level optimization is utilized. For the aleatoric uncertainty, advanced MONTE-CARLO-based approaches are used. Deterministic physical models are referred to as basic solution in the uncertainty quantification scheme. In this contribution the stochastic analysis is replaced by a surrogate model and the uncertainty model of fuzzy probability-based randomness (fp-r) is investigated. An inclusion of ANNs in the polymorphic uncertainty quantification scheme of fp-r is proposed, which contains automatic training data generation, hyper-parameter training and ANN evaluation. The novel method is capable of evaluating the quality of the results and automatically improving the quality of the predicted results by computation of new training data. For the validation of the surrogate model estimations, the error indicator introduced in (Schmidt et al., 2018) is extended. In the case that low quality of the results is indicated, additional training data is generated within the area of low quality. If the newly sampled training data cannot be adequately approximated anymore by the ANN due to an insufficient ANN design, the structure is re-optimized and the ANN is re-trained. Training data and network output have different orders of magnitude. Hence, a filter is developed in order to achieve normalization and save numerical effort.

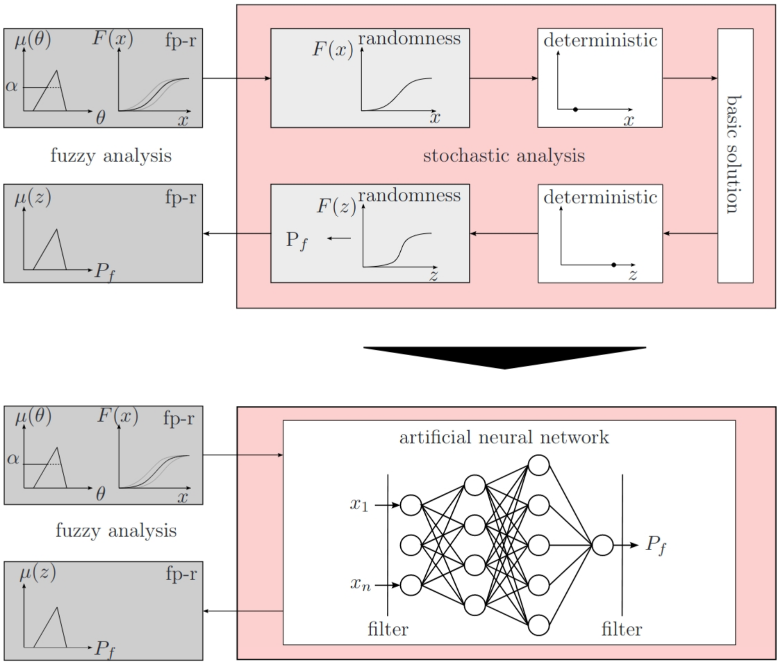

Fig. 1. General analysis scheme and replacement of stochastic analysis by an ANN as surrogate model – extended based on (Götz, 2017).

The capabilities and possibilities of the proposed algorithm and the error indicators are investigated and compared to the surrogate-free uncertainty quantification in a numerical example. Therefore, a structure provided by (Papaioannou et al., 2019) is investigated. With the proposed algorithm, the possibility of including ANNs as surrogate models in polymorphic uncertainty quantifications is shown and advantages within that methodology in terms of computational effort are demonstrated. The challenges of training data scaling and training data generation are investigated about their impact on the quality of results and on the computational effort.

Acknowledgements

The research activities result from the project 'Structural Design of Reinforced Concrete based on Multiscale Modelling and Polymorphic Uncertainty' within the Priority Program 1886 'Polymorphic Uncertainty Modelling for the Numerical Design of Structures'. The funding by the German Research Foundation (DFG) under grant KA 1163/37-2 and GR 1504/11-2 is gratefully acknowledged.

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