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Multiscale modeling of quasi-brittle materials based on artificial neural networks

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Incorporation of the microstructure can significantly improve the modeling of complex macroscopic material behavior [1]. This typically yields the drawback of high computational costs and can easily exceed the limit of currently available computational power. Data-driven concepts [2] and artificial neural networks (ANNs) provide a promising solution in this matter. ANNs are able to learn complex relations and can be evaluated fast, once trained.

We focus on quasi-brittle materials, where the macroscopic material behavior is strongly determined by cracks on the microscale. Instead of simulating the fully-resolved microstructure or applying the FE^2 method, an ANN is trained to predict the microstructural behavior and replaces a classical material model. Various simulations of artificial representative volume elements are carried out for training data. Additionally, the design and training process of the ANN is optimized in terms of the Rao-Blackwell theorem. The theorem, initially advocated in statistical modeling, allows the consideration of physical constraints [3] within the ANN framework.

We will demonstrate capabilities and limitations of ANNs for quasi-brittle damage modeling. Examples are given for heterogeneous pre-damaged states and discussed with respect to their physical behaviour and the numerical implementation.

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