
Neural networks methods for discovering multi-regional and biphasic hyperelastic properties

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Abstract

Constitutive material modeling is an important basis for mechanical analysis. Machine learning methods based on neural networks have been extensively used for the discovery of material constitutive laws. Recently, Flaschel et al. (1) proposed a new "unsupervised" framework that does not need any stress labels, which are usually difficult to measure in experiments. However, there is no work on the application of the unsupervised machine learning models for multi-regional constitutive models of heterogeneous materials. To address this issue, this paper develops a new unsupervised multi-regional constitutive learning model. In the implementation of this machine learning model, two indicators, i.e., the residual nodal force indicator and the free energy indicator, are first defined to identify nonhomogeneous interfaces or material distributions. Then, the combined identification of multi-regional constitutive models is conducted by adding a *switch function* to the extended strain invariants layer of the neural network. Finally, multi-regional constitutive models can be trained in one neural network at the same time. Besides, the proposed method has also been applied into the discovery of biphasic hyperelastic constitutive models, especially the equations of osmotic pressure. The effectiveness of the proposed model is verified through numerical simulation examples including an application to constitutive modeling of soft biological tissues undergoing regional damage.

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