LMS Seminar

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Automated discovery of generalized standard material models

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ABSTRACT

We propose a new approach for data-driven automated discovery of constitutive laws in continuum mechanics, which we denote as EUCLID (Efficient Unsupervised Constitutive Law Identification and Discovery). The approach requires no stress data but only displacement and global force data, which can be realistically obtained from mechanical testing and digital image or volume correlation techniques; it delivers interpretable models, i.e., models that are embodied by parsimonious mathematical expressions; it is one-shot, i.e., discovery only needs one experiment - but can use more if available. The basic mathematical tool enabling discovery is sparse regression from a large model space. For the construction of this space, we leverage the theory of generalized standard materials, which encompasses a plethora of important constitutive classes including elasticity, viscosity, plasticity and combinations thereof. We show that, based only on full-field kinematic measurements and net reaction forces, EUCLID is able to automatically discover the two scalar thermodynamic potentials, namely, the Helmholtz free energy and the dissipation rate potential, which completely define the behavior of generalized standard materials. The a priori enforced constraint of convexity on these potentials guarantees by construction stability and thermodynamic consistency of the discovered model; balance of linear momentum acts as a fundamental constraint to replace the availability of stress-strain labeled pairs; sparsity promoting regularization enables the automatic selection of a small subset from a possibly large number of candidate model features and thus leads to a parsimonious, i.e., simple and interpretable, model. Importantly, since model features go hand in hand with the correspondingly active internal variables, sparse regression automatically induces a parsimonious selection of the few internal variables needed for an accurate but simple description of the material behavior. A fully automatic procedure leads to the selection of the hyperparameter controlling the weight of the sparsity promoting regularization term, in order to strike a user-defined balance between model accuracy and simplicity. By testing the method on synthetic data including artificial noise, we demonstrate that EUCLID is able to automatically discover the true hidden material model from a large catalog of constitutive classes, including elasticity, viscoelasticity, elastoplasticity, viscoplasticity, isotropic and kinematic hardening.

BIOGRAPHY

Laura De Lorenzis received her Engineering degree and her PhD from the University of her hometown Lecce, in southern Italy, where she first stayed as Assistant and later as Associate Professor of Solid and structural mechanics. In 2013 she moved to the TU Braunschweig, Germany, as Professor and Director of the Institute of Applied Mechanics. There she was founding member and Chair (2017-2020) of the Center for Mechanics, Uncertainty and Simulation in Engineering. Since 2020 she is Professor of Computational Mechanics at the ETH Zürich. Prof. De Lorenzis and her group develop mathematical models and computational methods and perform experiments to observe, describe and predict complex phenomena involving the mechanics of solid materials.