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Data-driven Geometric Mechanics for Path-Dependent Materials

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ABSTRACT:

Plasticity models often include a scalar-valued yield function to implicitly represent the boundary between elastic and plastic material states. This paper introduces a new alternative where the yield envelope is represented by a manifold of which the topology and the geometry are learned from a set of data points in a parametric space (e.g., principal stress space, pi-plane). Here, deep geometric learning enables us to construct a highly complex and precise yield envelope by breaking it down into multiple coordinate charts. The global atlas that consists of these coordinate charts in return allows us to represent the yield surface via multiple overlapping patches, each with a specific local parametrization. This setup provides several advantages over the classical implicit function representation approach. For instance, the availability of coordinate charts enables us to introduce an alternative stress integration algorithm where the trial stress may project directly on a local patch and hence circumvent the issues related to non-smoothness and the lack of convexity of yield surfaces. Meanwhile, the local parametric approach also enables us to predict hardening/softening locally in the parametric space, even without complete knowledge of the yield surface. Comparisons between the classical yield function approach on the non-smooth plasticity and anisotropic cam-clay plasticity model are provided to demonstrate the capacity of the models for highly precise yield surface and the feasibility of the implementation of the learned model in the local stress integration algorithm. The relation between reduced order modeling and manifold-embedding constitutive modeling will be discussed.

BIOGRAPHY:

Dr. Sun is an associate professor at Columbia University and UPS Foundation visiting professor at Stanford University. He obtained his B.S. from UC Davis (2005); M.S. in civil engineering (geomechanics) from Stanford (2007); M.A. (Civil Engineering) from Princeton (2008); and Ph.D. in theoretical and applied mechanics from Northwestern (2011). Sun's research focuses on theoretical, computational, and data-driven mechanics for porous and energetic materials. He is the recipient of the IACM John Argyris Award (2022), NSF CAREER Award (2019), the EMI Leonardo da Vinci Award (2018), the Zienkiewicz Numerical Methods Engineering Prize (2017), AFOSR Young Investigator Program Award (2017), Dresden Fellowship (2016), ARO Young Investigator Program Award (2015), and the Caterpillar Best Paper Prize (2014).