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Connecting Fractal Structure to Fractional Order Properties in Solid Materials

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ABSTRACT:

In this talk, we will explore a method to uncover fractal structure and fractional order property relations in thermomechanical and viscoelastic materials. The methodology is based on entropy dynamics where Shannon's entropy is combined with fractional order constraints to obtain Bayesian posterior probability densities. This results in fat-tailed posterior densities where their maximum likelihood is evaluated using localized fractal and non-local fractional order operators to help predict material properties beyond conventional integer order operators. I will argue that the entropy dynamic approach provides a means to identify the appropriate fractal and/or fractional order operators as a function of (multi)fractal material structure. I will also emphasize how integer, fractal, and fractional order Taylor series expansions are very useful to understand when non-integer order operators become advantageous in model predictions. I will give examples for developing hyperelastic energy functions based on underlying multifractal structure, fractional order viscoelasticity and other fractal thermodynamic equations of state. The modeling framework is compared to experiments on dielectric elastomers, auxetic foams, 3D printed fractal structures, and energetic materials where the uncertainty in the fractal structure and the fractional constitutive properties are quantified.

BIOGRAPHY:

William Oates' research interests include solid mechanics, uncertainty analysis, fractal material behavior, network science, and quantum computing. He received his PhD in Mechanical Engineering from the Georgia Institute of Technology in 2004. He then studied nonlinear control as a post doctorate researcher in the Mathematics Department at North Carolina State University. Since joining the FAMU-FSU College of Engineering in 2006, he has worked in interdisciplinary research fields with collaborators in mathematics, chemistry, physics, and aerospace engineering all focused on multifunctional materials and adaptive structures for different applications in aerospace, robotics, and energy sciences. His research has been supported by DARPA, AFOSR, NSF, ARO, AFRL, DOE, and industry. His awards include the DARPA Young Faculty Award, the NSF CAREER award, ASME Gary Anderson Early Achievement Award, Guardian of the Flame Teaching Award, and ASME Fellow. His current research focuses on fractional and fractal order mechanics of polymers and energetic materials.