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Modeling in the time of Uncertainty: Combining continuum mechanics and Bayesian inference to compare models, account for scarce data and to classify biomaterials

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ABSTRACT:

The core of engineering is in quantitative decision making—we measure, estimate or compute various quantifiable attributes and combine the results with experience and prior knowledge to make decisions. Continuum mechanics has had a major impact in how various attributes are quantified,by the successful use of a combination of field-theoretical physical laws, empirical correlations and clever computing, However, there is a need to take the applications of continuum mechanics beyond quantification of attributes to unified decision making and inference.. In this presentation, I am going to highlight the combination of two areas: continuum mechanics and Bayesian inference techniques (borrowed from information theory and machine learning) to try and answer the following four questions:

(1)Parameter estimation for nonlinear continuum models : given the variability of nominally similar materials how do we capture the similarities in the response while retaining the spread?

(2)Learning and updating of parameters: How do we incorporate prior knowledge into the model and at the same time update our response(learn) in the light of new data

(3) Model Comparison: Given the fact that many different nonlinear continuum models all purport to "explain" the same data set, how do we compare different models and what could be the basis for selection

(4) Classification, Inference and Decision Making: Given training data that is known to belong to certain categories (such as "healthy" and "unhealthy") how do we compute the probability that a new data set belongs to a certain category?

These questions and their answers are not new---they have been addressed in the information theory , sensing , structural health monitoring, image processing and other communities for decades. However the combination of nonlinear continuum models (and the specific kinds of variability that occur) with these ideas throws up some new challenges (at least, the challenges were new to me) that we will discuss .

This is particularly relevant to biomechanics where it is not sufficient to "just" compute the arterial stress or blood flow patterns but be able to judge/decide whether the artery is diseased or whether an intervention is dangerous.

I will show two examples (1) the use of rather simple response functions to model tissue mechanics and to classify mechanical properties into categories and (2) a technique from image processing to distinguish Acute Coronary Syndrome and Coronary Artery Disease based on a chemical kinetics simulations of clotting of blood.

BIOGRAPHY:

Dr. Arun Srinivasa obtained a Batchelors Degree in Mechanical Engineering From the Indian Institute of Technology, Madras in 1986 and his PhD from U.C. Berkeley in 1991, working in the area of crystal plasticity and dislocation mechanics. He started his academic career at the University of Pittsburgh and subsequently moved to Texas A& M university in 1997, where is currently the Associate Department Head of the Mechanical Engineering Department at Texas A&M University and holds Holderedge/Paul Professorship for teaching. He is also the codirector of the TEES institute for Manufacturing Systems and an Adjunct professor in Applied Mechanics at IIT Madras, He works in the area of the elastic and inelastic response of a wide range of materials includnig metals, polymers, smart materials and soft biomaterials. He is also deeply involved in pedagogical research and especially in teaching with technology. He has published over a 100 archival articles in research and education and has published three books in the areas of thermomechanics of inelastic response and designing with shape memory alloys.