Yuri Bazilevs, Professor, School of Engineering, Brown University

Title

DDDAS for Systems Analytics in Applied Mechanics

Abstract

We will begin the presentation by providing an overview of the DDDAS concept, with a particular emphasis on the analytics of systems coming from the field of Applied Mechanics and focusing on the applications in Aerospace Structures. The main goal of DDDAS in this context is to provide a framework where the dynamic measurement data for a given system forms a symbiotic relationship with the advanced, geometrically complex, multi-physics model of that system to reliably predict its future behavior, shield it from undesired loading scenarios that accelerate failure, and estimate its remaining useful life. It is well known that aerospace composite materials and structures exhibit a strong multiscale behavior, which necessitates the development of a multiscale DDDAS framework where measurements and models interact at all the relevant spatial and temporal scales of the system of interest to maximize the resulting predictive power. We will present a set of examples, both academic and practical, that clearly illustrate that it is precisely the combination of dynamic data and advanced models, and not exclusively one or the other, that is needed to be truly predictive.

We will then shift gears and critically examine the modern data-driven approaches for systems analytics in applied mechanics. This topic, which has great relevance with DDDAS, has received significant attention in recent years. The applied mechanics community is trying to bring data science methods, such as Neural Networks (NNs), to bear on some of the key challenges, including the design of better materials and architected structures. NN-based approaches were also deployed as part of the so-called Physics Informed Neural Networks (PINNs) framework recently developed to bring more physics into predictions. PINNs accomplish this by defining an objective function that simultaneously minimizes the errors in the observed data, boundary conditions, and some form of the energy or PDE residual governing the problem at hand. A distinguishing feature of PINNs is that the discretization of a PDE does not make use of traditional methods like FEM, but rather NNs themselves. As a result, by construction, and in spirit, PINNs are yet another instantiation of the DDDAS concept that effectively blends data and physics-based models to achieve superior predictability. We will focus on the ability of approaches, incorporating NNs (as a tool) into DDDAS, to model large-deformation elastoplastic behavior of solids and structures and provide guidance for making such approaches more competitive than traditional modeling methods, so that they can be seamlessly integrated into structural systems analytics and beyond.

Bio

Yuri Bazilevs, is the E. Paul Sorensen Professor of Engineering. Bazilevs' research interests lie in the field of computational science and engineering with an emphasis on computational mechanics. Prior to that he was Vice Chair and Professor of Engineering in the Structural Engineering Department at the University of California, San Diego. His work addresses complex problems in the areas of biomedicine; renewable energy, and protecting infrastructures against disasters. He is the original developer of a computational technology called Isogeometric Analysis (IGA), which has had a significant impact in computational mechanics, and remains a prevailing research direction in the field today, and is a method that has advanced capabilities in the field of computational solid and structural mechanics. In addition, his work on fluid-structure interaction (FSI) analysis and the development of a fully-integrated FSI framework - methods and software, are employed in simulations for a range of industrial-scale applications, ranging from large civilian infrastructures to military aerospace systems.

Prior to joining the faculty at UCSD, he earned his Ph.D. in Computational and Applied Mathematics from the University of Texas-Austin in 2006, and his M.S. and B.S. in Mechanical Engineering from Rensselaer Polytechnic Institute in 2001 and 2000, respectively, and was J.T. Oden Postdoctoral Fellow at the Institute for Computational Engineering and Sciences (2006-2008) and a lecturer in the Department of Aerospace Engineering and Engineering Mechanics (2007-2008), both at the University of Texas-Austin.

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