Applied Mechanics Reviews

Editorial

Special Issue of Applied Mechanics Reviews in Collaboration With the Journal of Computational and Nonlinear Dynamics

Applied Mechanics Reviews (AMR) was founded in 1948 under the editorship of Lloyd Hamilton Donnell (1895–1997), in whose honor the biennial *Lloyd Hamilton Donnell Applied Mechanics Reviews Paper Award* was inaugurated in 2014. The founding of the journal, shortly after World War II, filled a void in the review of state-of-the-art research in applied mechanics, occupied before the war by the German periodical *Zeitschrift für Mechanik*. The inaugural volume included both Theodore von Kármán and Stephen Timoshenko as Editorial Advisors.

Over the years, the scope and purpose of AMR evolved. This reflected the changing nature of scientific research in the engineering sciences, the diversification of journal publications, and the development of alternative mechanisms for disseminating research among geographically distributed groups. Today, the journal aims to provide long-shelf-life, state-of-the-art survey articles, and retrospective reviews across all relevant subdisciplines of applied mechanics and engineering science, including fluid and solid mechanics, heat transfer, dynamics and vibration, and applications. Importantly, papers published in AMR emphasize added value beyond what is available in the existing literature. They do so through authoritative commentary and original synthesis, relating and contrasting the authors' original contributions to those of the community.

Beginning in 2014, AMR has collaborated with other ASME technical journals in developing special issues of AMR that collect contributions for a specific discipline in a single issue. Such special issues aim to bring to the fore topics that are of interest to the broader community as well as experts in the discipline, inviting cross-disciplinary collaboration, and welcoming new entrants to the field. Past collaborations include with the *ASME Journal of Pressure Vessel Technology* and the *ASME Journal of Vibration and Acoustics* in 2014; the *ASME Journal of Tribology* in 2017; and the *ASME Journal of Mechanisms and Robotics* in 2018.

This special issue of AMR is developed in collaboration with the *ASME Journal of Computational and Nonlinear Dynamics* (JCND). Since its founding in 2005, JCND has served as a medium for rapid dissemination of original research results in theoretical and applied computational and nonlinear dynamics. The journal has been a forum for the exchange of new ideas and applications in rigid and flexible multibody system dynamics and all aspects—analytical, numerical, and experimental—of dynamics associated with nonlinear systems. The broad scope of the journal encompasses all computational and nonlinear problems occurring in aeronautical, biological, electrical, mechanical, physical, and structural systems.

This issue features four review papers exemplifying state-of-the-art research in computational dynamics, stochastic dynamics, nonlinear dynamics, and multibody dynamics. Two of these papers are accompanied by commentary by an independent set of authors, as well as responses to this commentary by the original authors. The conversation that thus arises reflects the vibrancy of dynamics research and catalyzes further technical advances.

Extreme events—infrequent, unanticipated, but able to cause widespread devastation and disruption—are found in many large-scale natural and engineered systems, ranging from earthquakes, ocean waves, and epidemics to transportation, power, and financial systems. The review by Farazmand and Sapsis focuses on self-sustaining mechanisms underlying the occurrence of such events, for example, bursting in slow-fast dynamical systems, and on the most likely routes through state space associated with rare noise-induced transitions between equilibria. They describe a recently developed variational technique that combines model information and statistical data to identify states in the *domain of attraction* of such extreme events and show how this may be used, for example, to explain the formation of rogue waves in deep sea conditions. Such insights are then used to formulate indicators for real-time prediction of extreme events and to consider desirable performance characteristics for such indicators, specifically the likelihoods of false positives and false negatives. In their commentary, Grigoriu and Uy provide additional discussion of the origins of extreme events, particularly those caused by random inputs with heavy tails that are shown to produce large, infrequent excursions even for very simple dynamical systems. They further discuss the use of spectral measures from multivariate extreme-value distribution theory to characterize indicator reliability and performance. These contributions collect a body of knowledge that facilitates ongoing and future studies of extreme events and, importantly, provides a basis for efforts to mitigate against extreme events in engineering systems.

Many natural and engineered phenomena, ranging from mud slides to additive manufacturing processes, can be effectively described in terms of flows of large numbers of interacting grains of material according to principles of granular dynamics. In the review by Corona, Gorsich, Jayakumar, and Veerapaneni, the authors apply a recently proposed tensor-decomposition technique to the solution of nonlinear complementary problems associated with discrete-element modeling simulations of such granular media. They demonstrate their approach using three model problems from terramechanics: sedimentation in a box with a rotating mixer; granular flow in response to the lateral sinusoidal motion of a rectangular blade in a fixed container; and shearing of a soil sample subjected to a normal load force. The analysis validates a predicted order-of-magnitude speed-up compared to other state-of-the-art preconditioning techniques and a practically size-independent scaling of precomputation costs for problems with tens or hundreds of thousands of particles. The discussion is accompanied by pseudo-code implementations of the key algorithm and detailed performance data, characterizing the scaling with problem size and number of collisions. Given the focus in this paper on primary-dual interior point methods used to solve constrained convex optimization problems, it is suggested that the tensor-decomposition approach should produce similar benefits to the solution of many other large-scale and sparse optimization problems.

The article by Mitra and Epureanu and the commentary by Wallaschek, Panning-von Scheidt, and Willeke are concerned with the dynamics of rotating bladed disks, critical structural components of turbomachines used in rocket engines, jet engines, and gas and steam turbines. Mitra and Epureanu review projection-based reduced-order modeling techniques for bladed disk structures that experience localized frictional and intermittent contact with their environment, e.g., turbine shrouds. Here, the focus is on deviations from a nominally linear vibration analysis for a structure with cyclic symmetry due to mistuning of geometric, inertial, or material properties of individual blade sectors or nonlinearities associated with localized or distributed contact, as well as cracks or other defects. As described in great detail by the authors, an understanding of the influence of such deviations allows one to construct basis motions onto which the full dynamics may be projected with limited loss of resolution and predictive power. Of course, such an understanding also points to the pitfalls of the reduction approach and opportunities for further development. To this point, the commentary articulates the potential value of a multimodel reduction approach to account for different operating conditions and contact assumptions.

The treatment of large numbers of simultaneous contacts in the modeling of granular flows motivates the development of accelerated numerical techniques in the paper by Corona et al. Similarly, the nonlinearities inherent in intermittent contact in rotating turbomachinery necessitate the art and science of reduced-order modeling reviewed by Mitra and Epureanu. A complementary perspective on contact, impact, and friction is provided in the paper by Natsiavas. Here, the focus is on the analytical modeling of contact problems in terms of piecewise smooth, commonly low-dimensional, dynamical systems, and on an extensive and growing literature concerned with predictions of the resultant system dynamics and associated bifurcations. The discussion covers the by-now classical treatment of rigid-body collisions using the Darboux-Keller approach and techniques of nonsmooth mechanics relying on measure-differential inclusions and complementarity principles. It proceeds to reflect on recent attempts to unfold and appropriately scale the transition across, or through a neighborhood of, a model discontinuity. These include the author’s own work on resolving the contact phase using concepts from differential geometry; the regularization of hidden dynamics using slow-fast modeling of piecewise smooth flows by Jeffrey; and Szalai’s derivation of low-dimensional corrections to asymptotic (and inherently incomplete) piecewise smooth models of intermittent contact in deformable structures.

Collectively, the papers in this special issue exemplify the breadth of concerns of the disciplines of computational and nonlinear dynamics. They document the ever-increasing sophistication of the questions asked of dynamical systems and the techniques employed for their resolution. We hope and anticipate that the content of this collaborative issue of AMR and JCND will be a resource to the applied mechanics and dynamics communities alike for quite some time to come.

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