Applied Mechanics Reviews

Editorial

Special Issue of Applied Mechanics Reviews in Collaboration With the Journal of Mechanisms and Robotics

ASME *Applied Mechanics Reviews* (AMR) is an international review journal that serves as a premier venue for state-of-the-art and retrospective surveys and reviews of research and curricular developments across all subdisciplines of applied mechanics and engineering science, including fluid and solid mechanics, heat transfer, dynamics and vibration, and applications. AMR works closely with other ASME Technical Journals to collect contributions for a specific discipline in a single issue of AMR in order to serve the ASME community with unique content of high quality and long shelf life. Past special issues of AMR include collaborations with the ASME Journal of Pressure Vessel Technology in January 2014, the ASME Journal of Vibration and Acoustics in July 2014, and the ASME Journal of Tribology in November 2017.

Since its inception in 2009, the ASME Journal of Mechanisms and Robotics (JMR) has emerged as the leading resource for up-to-date information on fundamental theory, algorithms, design, manufacture, and experimental validation for mechanisms and robots. The current scope of the journal includes topics in theoretical and applied kinematics; mechanism synthesis and design; analysis and design of robot manipulators, hands, and legs; soft robotics and compliant mechanisms; origami and folded robots; printed robots; and haptic devices. The journal is also interested in novel fabrication, actuation, and control techniques for mechanisms and robotics; bio-inspired approaches to mechanism and robot design; and the mechanics and design of micro- and nanoscale devices.

The goal of this special issue of AMR, developed in collaboration with JMR, is to focus on topics of importance to the community of educators, researchers, and practitioners interested in mechanisms, machines, and robots. The issue collects in-depth, state-of-the-art reviews of representative areas of these disciplines that emphasize both the fundamental and the applied, while being relevant to modern mechanical engineering and ongoing developments. The five featured reviews provide authoritative commentary on the existing literature on robot dynamics, parallel mechanisms, mechanism design, flying robots, and human–robot interaction. Independent expert discussions and author responses highlight complementary viewpoints and challenges for future research.

The review by Park, Kim, Jang, and Hong presents a beautiful tutorial on how the coordinate-free approaches of differential geometry, in general, (and matrix Lie groups, in particular) can be used to formulate equations of motion for multibody systems. Such intrinsic approaches lend themselves to symbolic computations and recursive algorithms for both inverse and forward dynamics, as well as for solving problems of optimal control. The authors show applications to mechanisms and robots with both open and closed chains, robots with unilateral constraints that arise from rigid body contact, as well as robots with compliance in the actuators. The commentary by Chirikjian and subsequent author closure provide further references and point the reader to cutting-edge work in the application of Lie group methods to noise-perturbed systems with many degrees-of-freedom.

The subject of review by Gosselin and Schreiber is the purposeful introduction of redundancy in the synthesis of parallel mechanisms, a subject that has received increasing attention in recent years in the design of machine tools and robots. The authors consider both kinematic and actuator redundancy associated with designs in which more internal degrees-of-freedom or actuators, respectively, are introduced than required in order to support a particular end-effector task. The review offers a detailed treatment of mathematical models, different classes of redundancy, and the singularities that are inherent in these mechanisms. Most importantly, the authors elaborate upon practical implications such as modulating the stiffness characteristic of these mechanisms (an important attribute in machine tools) and force transmission characteristics. The article also points to various architectures that can lead to the development of novel parallel mechanisms with a wide range of applications.

Flapping-wing designs have been shown to overcome the lack of maneuverability of fixed-wing designs, as well as inefficiency of rotary-wing solutions, at vehicle scales of a few centimeters or smaller. The comprehensive review by Helbling and Wood addresses actuation, energy, and power requirements for the control of such flapping-wing micro-aerial vehicles, inspired by the aerial acrobatics of flying insects. The paper describes propulsive mechanisms and actuation technologies, as well as the tradeoffs associated with different actuator, control, and propulsion methodologies. By the physics of scaling, traditional DC motors fall short of delivering power densities and bandwidths required for insect-scale robots. Instead, nontraditional actuation technologies, such as chemical muscles, custom electromagnetic actuators, and piezoelectric actuators, are shown to be more suitable for such vehicles. The authors describe the challenges in realizing autonomy and maneuverability in the context of an insect-scale prototype (the *RoboBee* project), where customization of all aspects of the lifecycle (design, electronics, actuation, control, and manufacturing) are necessary to meet the constraints of size, weight, and power. In the commentary by Gupta and author response, functional requirements and opportunities for significant advances in component technologies required to realize insect-scale flapping-wing vehicles are given further consideration.

Lang, Tolman, Crampton, Magleby, and Howell provide a highly visual review of recent advances in origami-inspired mechanism design and fabrication, a field that connects the intricacies of decorative paper folding to engineering applications across many physical scales and unexpected materials. Their focus is on thick origami, design problems in which thickness must be properly accounted for as folds are introduced along compliant linear regions of a material. The authors review the mathematical foundations for modeling zero-thickness origami mechanisms and proceed to highlight the challenges that originate with nonzero thickness applications, specifically the need to avoid self-intersection. Multiple design techniques are considered and compared, including the use of tapered or offset panels, hinge shifts, splitting of fold lines, use of rolling contacts, and various hybrid combinations. The authors also discuss the connection and trade-offs between the choices of thickness-accommodating design technique and manufacturing approach, as these affect the part count, material selection, and ultimate cost of production. The multilevel dependency across a design hierarchy between the kinematic problem of an origami design and the realization of a required physical mechanism is highlighted in the commentary by McAdams and the elaboration in the author response on the notion of a "wicked problem."

Physical human–robot interactions take center stage in the systematic state-of-the-art survey by Losey, McDonald, Battaglia, and O'Malley. Their discussion is concerned with applications in which robots and humans cooperate to perform a physical task or in which a robot augments human physical function, including in teleoperation. Focus is placed on applications in healthcare that critically depend on such physical interactions, e.g., rehabilitation robotics and prosthetic limbs. Accordingly, the authors discuss how robots can detect human intention by defining, measuring, and interpreting intent while physically interacting. They then address the arbitration of roles in tasks where control is shared between robot and human. Finally, they analyze the role of feedback in collaborative tasks, focusing on the very important haptic sensory channel. Case studies from two healthcare applications illustrate the framework in the context of typical problems of shared control with haptic and/or visual feedback. The commentary by Schmiedeler and Wensing provides a deeper dive into the significance of proper mechanical design to facilitate intent detection, the use of models to effectively modulate shared control, and the advantages and disadvantages of finite-state machines for updating the robot's goal behavior. The author response points to active research into intent detection and control arbitration in continuous spaces in order to ensure safe and successful collaboration.

We hope that this collaborative issue of AMR and JMR will be a resource to both the applied mechanics and mechanisms-and-robotics communities, and that it will nucleate high-impact, collaborative education and research efforts.

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