Journal of Mechanisms and Robotics

Guest Editorial

Special Issue: Selected Papers From IDETC-CIE 2020

This special issue of the ASME *Journal of Mechanisms and Robotics* is a compendium of 25 of the best papers submitted and presented at the 44th ASME Mechanisms and Robotics Conference during the 2020 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference (IDETC/CIE 2020).

The ASME Mechanisms and Robotics Conference provides researchers an international platform to present their latest work in the theory, design, and applications of mechanical and robotic systems. In recent years, the conference has also seen an unprecedented number of papers on contemporary topics, such as soft- and human-safe robots, origami-mechanisms, rehabilitation and medical robots, exoskeleton/prosthesis, and mechanism-based metamaterials. This special issue represents exciting topics including, compliant- and origami-mechanisms, parallel robots, rehabilitation and wearable robotics, mechanism design, robotic joints, bio-inspired robotic mechanisms, cable-driven robots and actuators, and control methods for robotics.

While the conference had received 123 papers, based on the conference reviews and input of the conference organizers, guest editors invited 19 papers for a full review and 14 additional papers were independently submitted by authors. Out of these 33 papers, 25 were finally accepted for this special issue.

Three of the papers explore topics in theory and applications of compliant- and origami-mechanisms. As the research community in compliant- and origami-mechanisms continues to grow in depth and maturity, these papers represent some of the diversity of thought within the field. Gallego et al. propose an approach for quasi-static balancing of four-bar linkages with torsion springs to design statically balanced fully compliant mechanisms. The positive stiffness exhibited by torsion springs at revolute-joints is compensated by a negative stiffness created by a non-zero-free-length linear spring. Pham and Hernandez present a modeling and design exploration study of a novel twisting wing whose motion is enabled by a tensegrity mechanism. It is shown via computational fluid dynamics analyses that the twisting wing displays a higher lift-to-drag ratio than the conventional wing, and hence, the twisting wing is more aerodynamically efficient. Pratapa et al. analyze the folding kinematics of the Morph pattern in origami-based tessellated structures. This pattern can result in multiple hybrid states which can be used in reprogrammable morphing systems.

This special issue features three papers on parallel robots. Damerla and Awtar present a constraint-based analysis of the performance attributes of existing parallel wrist mechanisms, including their degrees-of-freedom, load transmission capability along these DOFs, and load-bearing capability along constraint directions. The analysis reveals performance trade-offs among the performance attributes for a given mechanism and design trade-offs across these mechanisms. Kuo and Dai discuss the structural synthesis of a special class of parallel manipulators with fully decoupled motion. They present a systematic approach for synthesizing the structures of f-DOF ($f <= 6$) parallel manipulators with fully decoupled projective motion and utilize it to design several example manipulators. Rico et al. present a screw theory-based method for determining the mobility of fully parallel platforms. The process includes the intersection of the subalgebras of Lie algebra Special Euclidean Group in 3 dimensions (SE(3)) associated with the legs of the platform and the analysis of the possibility of the legs generating a sum or direct sum of two subalgebras of the SE(3).

There are four unique papers on rehabilitation and wearable robotics in this issue. Zhang et al. present a novel robotic system to characterize and retrain reaching in rats (robotic arm training system) intended to be a research platform for the rehabilitation of forelimb movements. The paper describes the design requirements, mathematical models, and details of the physical device. Zhao et al. present a clustering-based machine learning technique to find a limited number of motion patterns for upper-limb rehabilitation so that they could represent a large amount of those from people who have various body parameters. The construction of the integrated system as well as an experimental trial of the prototype is presented in the paper. Jalgaonkar et al. present the design of an ankle rehabilitation robot that has decoupled degrees-of-freedom. The design allows for more natural ankle motion that accounts for biological and mechanism misalignment. Liang Lau and Song Soh present a new wearable device concept that comprises a CF strain-voltage sensor embedded as part of an inverted slider-crank mechanism for joint extension sensing. This has the benefit of not requiring anthropometric information from the user to relate the joint parameters to the fabric strain readings, as opposed to an existing design.

This special issue also features four papers on planar and spatial mechanism design. Sherman et al. develop a method based on kinematic equations to construct cognates that arise from permuting link rotations. Using the proposed method, they reproduce all known results for cognates of planar four-bar and six-bar linkages and construct a cognate of an eight-bar and a ten-bar linkage. Kong presents the construction and reconfiguration analysis of a spatial mechanism composed of four circular translation (G) joints. The approach in this paper can be extended to the analysis of other types of coupled mechanisms using cables and gears and multi-mode spatial mechanisms involving G joints. She et al. present a continuously tunable stiffness arm for safe physical human–robot interactions. This paper details the design and modeling of a compliant robotic arm whose stiffness can be continuously tuned via cable-driven mechanisms actuated by a single servo motor. The variable stiffness arm design developed in this study could be a promising approach to address safety concerns for safe physical human–robot interactions. Woodland et al. demonstrate that conical developable mechanisms can have rigid motion. This work shows a significantly different approach to develop both classical and novel developable mechanisms.

Two papers related to robotic joints are presented in this special issue. Seymour et al. present a study on adapting traditional hinge options to achieve revolute motion in cylindrical developable mechanisms. A brief overview of options is given, including classical pin hinges, small-length flexural pivots, initially curved beams, and an adaptation of the membrane thickness–accommodation technique. Nelson et al. examine the ability to deploy a planar surface to a desired convex profile with a simple actuation. A system of rigid links joined by equating torsion spring spacing along the horizontal axis of deployed parabolic profiles shown results in minimizing the area between the model's rigid-link approximation and smooth curve.

This special issue also features two papers on bio-inspired robotic mechanisms. Venkateswaran et al. present an optimization approach for the design of a piping inspection robot that moves like a caterpillar. Tensegrity mechanisms are added between the motor modules to make the robot flexible to pass through the bends, and the size of the robot assembly is optimized. Liu and Ben-Tzvi develop an extensible continuum manipulator that combines a rigid coupling hybrid mechanism concept with a flexible parallel mechanism. The resulting manipulator has improved dexterity and workspace.

There are also two unique papers on the special issue on the topic of cable-driven robots and actuators. Metillon et al. present the design, modeling, and prototyping of a hybrid robot composed of a Cable-Driven Parallel Robot mounted in series with a parallel spherical wrist (PSW) that exhibits a large translational workspace and an unlimited orientation workspace. Moore and Schimmels present the design of a variable stiffness actuator using quadratic antagonistic cables. The resulting actuator has a large range of linear stiffness which can be used in more dextrous robotic fingers.

Lastly, this special issue features five papers related to various control methods for robotics. Kumar et al. prove the relative linear velocity is bounded for conformal fingertips in robotic hands with soft fingers. Using this result, they develop a metric of slip which in turn is used in a control methodology to regulate the internal forces in robotic hands with soft fingers. Tang and Notash apply neural network-based transfer learning to the kinematics of a two degrees-of-freedom robotic arm. This approach can speed up the training process and increase computation efficiency. Canfield et al. present a model and model calibration of a collaborative welding robot to aid in teaching and monitoring welding tasks. The improved model was shown to be effective when implemented in a commercial robot. Allevato et al. use a modified derivative-free system identification technique based on neural networks and visual observation. The method is applied to estimate parameter differences between a proposed model and a target model of a five-parameter model of a marble rolling in a robot-controlled labyrinth game mechanism. Peng et al. present the ability of a biped robot to maintain single support (SS) or double support (DS) contact and to achieve a step represented by balanced and steppable regions, respectively, as proposed partitions of augmented center-of-mass-state space. The implemented hip–knee–ankle controller resulted in improved stabilization with respect to decreased foot tipping and time required to balance, relative to an existing hip–ankle controller and a gyro balance feedback controller.

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