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Guest Editorial

Special Section: Design, Analysis and Actuation of Reconfigurable Parallel Mechanisms

This Special Section with 11 papers aims to share research efforts in design, theory, development, and applications for Reconfigurable Parallel Mechanisms (RPMs) building on work first presented at the Fourth International Conference on Fundamental Issues, Applications and Future Research Directions for Parallel Mechanisms/Manipulators/Machines (World Parallel 2020).

This premier conference is held every 6 years—the fourth edition was hosted on September 9–11, 2020, in Belfast UK led by Professor Yan Jin from Queen's University Belfast and Professor Jian S. Dai from King's College London. It builds upon the first edition in Québec City in 2002, organized by Prof. Clément Gosselin, from Laval University and Prof. Imme Ebert-Uphoff from Georgia Tech; the second edition was held in Montpellier in 2008 by Profs. François Pierrot, Nicolas Andreff, Olivier Company, Marc Gouttefarde, and Sébastien Krut, and the third edition was held in Tianjin in 2014 by Prof. Tian Huang from Tianjin University and Prof. Jian S. Dai from King's College London.

Over the past 20 years, reconfigurable mechanisms have generated great interest worldwide and attracted many researchers. As a field of study, mechanisms have evolved from a conventional mechanism philosophy with a fixed topology and fixed structure to encompass a class of mechanisms that vary in topology, structure, and mobility. This evolution has resulted in the development of reconfigurable parallel mechanisms (RPMs) with variable degrees-of-freedom that are mechanically intelligent and capable of adapting to constantly changing conditions. In their various forms, these RPMs meet the growing requirements in healthcare, manufacturing, energy, domestic automation, and in search, rescue and disaster relief, and planetary exploration, etc.

In order to effectively operate in their reconfigurable states to be adaptable to dynamic working environments, challenges in theoretical kinematics and in design need to be tackled and addressed. These include design theory, bifurcation, singularity, calibration, morphing, kinetostatics, trajectory, and homotopy continuation. The use of reconfigurable parallel mechanisms can be seen in tensegrity mechanisms, inflatable actuators, climbing robots, and transformable mobile robots. The actuation of reconfigurable parallel mechanisms can also be envisioned using shape memory alloys and various actuation approaches.

In this Special Section, a number of the latest developments are presented. In the context of design, Zhang and Liu present a reconfigurable parallel manipulator by introducing hybrid kinematic limbs with kirigami-inspired plano-spherical linkages which allow the platform mobility to change. Suthar and Jung present a metamorphic parallel twisted-scissor mechanism by introducing metamorphic segments in contrast to a conventional scissor mechanism, which increases bending stiffness and improves performance.

In the topic of topological reconfiguration, Spinos et al. introduce a new class of self-reconfigurable robots with a variable geometry truss. The topology network they introduce enables high-level planning and provides insights into the design of truss topologies. The reconfigurability leads to balancing. A method of resorting to a passive energy element is introduced by Kuo et al. for statically balancing a reconfigurable mechanism, where both spring-based and counterweight-based designs are used, leading to a reduction of the actuation torque during reconfiguration.

Considering the driving torque, Cui et al. present a distribution method to optimize the driving torque and energy consumption, leading to an optimal design that takes the singular configuration away from the required workspace. In exploiting redundancies for workspace enlargement and joint trajectory optimization, Wen and Gosselin present a method for detecting mechanical interferences between two links that are not directly connected for evaluating the workspace. The method is readily applicable to other kinematically redundant hybrid parallel robots.

In singularity loci and bifurcated evolution with configuration transitions, a reconfigurable legged mobile lander is introduced by Han et al. The actuated limb has three alternative phases of rotations and the mobile lander performs both active and passive mobilities provided by the touchdown impact force. The paper presents all four bifurcated evolution routes for configuration transitions.

In the dual drives with exchangeable flexure joints, Shen et al. present a generalized analytical kinetostatic model based on the beam constraint model and estimate variables of the rotation angle of the cross-arm and the net driving force. In the topic of stiffness evaluation, Chen et al. present a stiffness isotropy index for evaluating the stiffness of an absorption robot for large-scale structural parts processing. In the study of tensegrity, Shen et al. present decoupled and anisotropy design of the stiffness and joint equivalent design for producing a new compliant joint. The joint achieves a good elastic response and reduces the maximum axis drift, with high mechanical efficiency, modularity, and scalability.

In the topic of design optimization, Yang et al. present a reduced design optimization formulation by reducing the traditional optimization over the entire workspace to maximize the manipulability over the total orientation workspace, leading to a larger orientation workspace with a good precision performance in the case of a Schöflies-motion parallel manipulator with rotational pitch motion. The methodology is applicable to reconfigurable mechanisms.

We hope that this Special Section provides greater impetus to the burgeoning research and applications in reconfigurable parallel mechanisms (RPMs).

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