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Editorial

New Frontiers in Parallel Robots

Zhufeng Shao [1,*], Dan Zhang [2] and Stéphane Caro [3]

1 Department of Mechanical Engineering, Tsinghua University, Beijing 100084, China
2 Department of Mechanical Engineering, Lassonde School of Engineering, York University, Toronto, ON M3J 1P3, Canada
3 Nantes Université, École Centrale Nantes, CNRS, LS2N, UMR 6004, F-44000 Nantes, France
* Correspondence: shaozf@mail.tsinghua.edu.cn

Citation: Shao, Z.; Zhang, D.; Caro, S. New Frontiers in Parallel Robots. *Machines* **2023**, *11*, 386. https://doi.org/10.3390/machines11030386

Received: 13 March 2023
Accepted: 13 March 2023
Published: 15 March 2023

In the field of parallel robots, marked by the birth and application of the Gough–Stewart parallel mechanism [1] in the 1960s, great progress has been made in the past 60 years. The most notable feature of a parallel robot is that there are multiple closed-loop branch chains jointly connecting and driving the moving platform [2], which gives great flexibility in its configurations, creating a new way to change performance through robot configuration. Parallel robots usually have outstanding advantages of high stiffness, high precision, and high speed [3], which make up for the performance shortcomings of serial robots. The abundant configurations and complex mechanisms of parallel robots also present challenges in terms of configuration synthesis, performance evaluation, modeling, calibration, control, etc. Opportunities coexist with challenges, and parallel robots attract attention from both academia and industry. Today, parallel robots are constantly enriched, and new types of parallel robots, such as cable-driven parallel robots (CDPRs) [4], soft parallel robots [5], and hybrid robots [6], are constantly emerging. In particular, while inheriting the abovementioned advantages, a CDPR has the advantages of low cost, high energy efficiency, easy reconfiguration, and light weight, showing great application potential in scenarios such as large working spaces, heavy loads, high speeds, and bionics [7,8]. Parallel robotics research and applications show continued vitality and are expected to transform the industry in the future.

This Special Issue provides an international forum for professionals, academics, and researchers to present the latest developments from theoretical studies and applications of parallel robots. It includes 10 selected papers, covering important aspects of parallel robots such as modeling and control, error analysis and calibration, singularity analysis, and trajectory planning. The contents of these studies are briefly described here.

In [9], an evaluation model is established to analyze the influence of geometric errors on limbs' comprehensive deformations for an over-constrained parallel manipulator. The evaluation model is established based on kinematics and verified through simulations. Two global sensitivity indices are proposed, and a sensitivity analysis is conducted using the Monte Carlo method throughout the reachable workspace. The geometric errors that have greater effects on the average angular comprehensive deformation are identified.

In [10], a consistent solution strategy for static equilibrium workspaces of different types of under-constrained cab-driven robots is presented. The dynamic models and parameters that are applied to make the system stable for point-to-point movements are introduced. The constraints of the dynamics model are incorporated into the trajectory planning process to achieve point-to-point trajectory planning for the under-constrained cable-driven robots.

In [11], the authors present the singularity analysis and the geometric optimization of a 6-DOF (Degrees of Freedom) parallel robot for SILS (Single-Incision Laparoscopic Surgery). Based on a defined set of input/output constraint equations, the singularities of the parallel robotic system are determined and geometrically interpreted. Then, the geometric parameters for the 6-DOF parallel robot are optimized to make the operational workspace singularity-free.

Paper [12] focuses on pick-and-place trajectory planning and tracking control of a cable-based gangue-sorting robot in the operation space. A four-phase pick-and-place trajectory planning scheme based on an S-shaped acceleration/deceleration algorithm and the quantic polynomial trajectory planning method is proposed. A robust adaptive fuzzy tracking control strategy is presented against inevitable uncertainties and unknown external disturbances. The proposed method guarantees a stable and accurate pick-and-place trajectory tracking process.

Paper [13] proposes a fractional-order impedance control scheme, named KDHD, in which additional damping is added, proportional to the half-order derivatives of the end-effector position errors according to the half-derivative damping matrix, HD. The proposed impedance controller represents an extension to multi-input multi-output robotic systems of the $PDD^{1/2}$ controller for single-input single-output systems, which over performs the PD scheme in the transient behavior.

Paper [14] focuses on the dynamic modeling, workspace analysis, and multi-objective structural optimization of a large-span, high-speed, cable-driven parallel camera robot. The curved cable, due to the self-weight, is modeled as a catenary, and the dynamic model is derived by decomposing the motion of the cable into an in-plane motion and an out-plane motion. An optimization model is presented to simultaneously improve the workspace volume, anti-wind disturbance ability, and impulse of tensions on the camera and pan-tilt device system (CPTDS).

In [15], the authors present kinematic and dynamic modeling and workspace analysis for a novel suspended CDPR which generates Schönflies motions. The kinematics of the CDPR are solved through a geometrical approach. The dynamic feasible workspace of the robot is determined. Experiments are performed on a prototype of the robot to demonstrate the correctness of the derived models and workspace.

Paper [16] proposes a new method for the kinematic calibration of parallel robots to strict pose error bounds. The new method includes a new pose error model with 60 error parameters and a different kinematic parameter error identification algorithm based on L-infinity parameter estimation. Parameter errors are identified by using linear programming. The feasibility and validity of the proposed kinematic calibration are verified through both simulations and experiments.

Paper [17] studies the 3-DOF cutting stability and surface quality optimization of a parallel kinematic manipulator (PKM). A prediction model for the 3-DOF stability of helical milling based on the PKM is established through a semi-discrete method based on the natural frequency analysis of the PKM and a cutting force model of titanium alloy helical milling. A step-cutter is used to improve the machining process by enhancing the stability domain. The proposed method can provide a reference for further optimization of the prediction and optimization of the milling of difficult-to-process materials based on a PKM in the future.

In [18], the authors develop a simple model to evaluate the first natural frequencies of over-constrained PKMs. The PKM legs are modeled by beams, and constraint equations between the parameters are determined according to screw theory. The focus of this paper is to determine the global mass and stiffness matrices of the PKM in stationary configurations without the use of Jacobian matrices. The proposed method can be easily used at the conceptual design stage of PKMs.

The Guest Editors thank all of our colleagues who have taken interest in this Special Issue, especially the authors of the papers published in this Special Issue. All the of papers underwent a rigorous review process to ensure the high quality of the publications. We are grateful to the reviewers who evaluated these papers and provided valuable comments based on their professional perspectives. We also would like to thank the editors from MDPI for their support and effort in the organization and publication of this Special Issue.

It is hoped that the papers published in this Special Issue can be used as vehicles to promote knowledge sharing in the field of parallel robots. More importantly, we hope more people will be informed about and understand parallel robots and their latest technologies and actively participate in the innovation, research, development, and application promotion of parallel robots.

Author Contributions: Conceptualization, Z.S., D.Z. and S.C.; writing—original draft preparation, Z.S.; writing—review and editing, D.Z. and S.C. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Natural Science Foundation of China (No. U19A20101) and the National High-tech Ship Research Project of China (No. MC-202003-Z01).

Acknowledgments: We express great thanks to the editors of MDPI for their excellent support for this Special Issue, and it would have been impossible without their persistence and help. Many thanks to all our colleagues who are interested in these research topics and submitted their research for our Special Issue. A special thanks to the reviewers for their efforts and time spent in order to maintain the high quality of all contributions.

Conflicts of Interest: The authors declare no conflict of interest.

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