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Editorial

Recent Trends on Innovative Robot Designs and Approaches

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1. Introduction

The use and function of robots are evolving at a fast pace, sparking interest in creative solutions within a quickly expanding potential market in cutting-edge industries with applications including service robotics, surgical and rehabilitative robotics, and assistive robotics. In this context, fresh ideas, approaches, and applications still require considerable attention. For example, assistive robotics, surgical and rehabilitative robots, service robotics and other cutting-edge application domains are becoming increasingly important, not only from a technological and financial standpoint but also in terms of their consequences for daily life and society as reported for example in [1–12]. Even the use and function of robots on assembly lines and in other conventional frameworks are being extensively altered in favor of innovative flexible and agile manufacturing methods. Novel designs are also being extensively researched, including cable-driven parallel robots (CDPRs), as their conceptual design can provide a key performance in terms of large workspace, reconfigurability, large payload capacity, and dynamics [13–16].

This Special Issue aims at attracting cutting-edge research and review articles on any innovative robot design or modelling/control approach. The published papers in this Special Issue cover a wide range of topics, including robot manipulation, variable stiffness actuation, mobile system, social robotics, task optimization, robot compliance, biomedical devices, collaborative robotics, trajectory planning, and wearable robotics. The first published paper presents the concept of a robotic system for the aliquoting of biomaterials, consisting of a serial manipulator in combination with a parallel Delta-like robot. This is particularly valuable to avoid the risks of contaminations as reported with a design solution and simulation models in [17]. The second paper addresses the concept of "Industry 4.0" as based on the utilization of collaborative robots [18]. In particular, authors present a gestural framework for controlling a collaborative robotic manipulator using pointing gestures. A unique robotic collaborative workspace called the Complex Collaborative HRI Workplace (COCOHRIP) was designed around the gestural framework to evaluate the method and provide a basis for the future development of HRI applications [18]. The third paper focuses on robots for rehabilitation tasks by presenting the development of an internal torque monitoring system for ASPIRE, a parallel robot designed for shoulder rehabilitation. A complete analysis regarding the components of the robotic system is carried out with the purpose of determining the dynamic behavior of the system, as reported in [19]. The fourth paper addresses the structural-parametric synthesis and kinematic analysis of the RoboMech class of parallel mechanisms (PM) having two sliders. The proposed methods allow the synthesis of a PM with its structure and geometric parameters of the links to obtain the given laws of motions of the input and output links (sliders). The paper outlines a possible application of the proposed approach to design a PM for a cold-stamping technological line, as reported in [20].

The fifth paper presents novel models of reconfigurable parallel mechanisms (RPMs) with a single active degree-of-freedom (1-DOF). The mechanisms contain three to six identical kinematic chains, which provide three (for the tripod) to zero (for the hexapod) uncontrollable DOFs. Each kinematic chain in the synthesized mechanism consists of planar and spatial parts. Such a design provides them with reconfiguration capabilities even when the driving link is fixed. This allows the reproduction of diverse output trajectories without using additional actuators, as reported in [21]. The sixth paper presents a mechanical design of a four degrees of freedom (DOF) wheelchair-mounted upper limb exoskeleton. The design takes advantage of a non-back-drivable mechanism that can hold the output position without energy consumption and assist the completely paralyzed users. Preliminary results are provided to show the effectiveness and reliability of using the proposed design for physically disabled people, as reported in [22]. The seventh paper deals with the optimal design of a planar cable-driven parallel robot (CDPR), with three degrees of freedom, intended for assisting the patient's affected upper limb along a prescribed movement. A prototype of the optimal design of the CDPR was developed and validated experimentally, as reported in [23]. The eighth paper addresses the development of ResQbot 2.0—a mobile rescue robot designed for performing casualty extraction. The proposed design and development of the mechanical system as well as the method for safely loading a full-body casualty onto the robot's 'stretcher bed', are described in detail, as reported in [24]. The nineth paper deals with the Instant center that is an important kinematic characteristic which can be used for velocity and singularity analysis, configuration synthesis and dynamic modeling of multi-degree of freedom (multi-DOF) planar linkages. The paper proposes two criteria to convert single-loop multi-DOF planar linkages into a two-loop virtual linkage by adding virtual links. The proposed method can be applied to a wide range of single-loop multi-DOF N-bar ($N \geq 5$) planar linkages, as reported in [25]. The tenth paper deals with the synthesis of the kinematic structure of a robotic manipulator to determine the optimal manipulator for a given task by proposing four different algorithms using the standard Denavit–Hartenberg convention and Bézier splines approximation and vector algebra. The results are demonstrated with three chosen example poses and are evaluated by measuring the manipulability and total link length of the final kinematic structures, as reported in [26].

The eleventh paper refers to robotic deburring by proposing a mechanism that can automatically reduce cutting forces in the event that the burr is too high, and is able to return to the baseline configuration when the burr thickness is acceptable again. The effectiveness of the proposed mechanism is verified by means of dynamic simulations using selected test cases. A reduction of 60% of the cutting forces is obtained, considering a steel burr 6 mm in height, as reported in [27]. The twelfth paper introduces a novel kinematic model for a tendon-driven compliant torso mechanism for humanoid robots, which describes the complex behavior of a system integrating rigid bodies with flexible actuation tendons. Inspired by the human spine, the proposed mechanism is based on a flexible backbone whose shape is controlled by two pairs of antagonistic tendons. Preliminary tests are reported to show the accuracy and efficiency of the proposed torso mechanism, as reported in [28]. The last paper introduces an innovative robotic foot design inspired by the functionality and anatomy of the human foot for a humanoid design. The proposed foot mechanism consists of three main bodies, to represent the heel, plant and toes, connected by compliant joints for improved balancing and impact absorption. The proposed design was validated with a numerical simulation, as reported in [29].

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References

1. Tai, K.; El-Sayed, A.-R.; Shahriari, M.; Biglarbegian, M.; Mahmud, S. State of the Art Robotic Grippers and Applications. *Robotics* **2016**, *5*, 11. [CrossRef]
2. Muñoz, J.; López, B.; Quevedo, F.; Barber, R.; Garrido, S.; Moreno, L. Geometrically constrained path planning for robotic grasping with Differential Evolution and Fast Marching Square. *Robotica* **2023**, *41*, 414–432. [CrossRef]
3. Gull, M.A.; Bai, S.; Bak, T. A Review on Design of Upper Limb Exoskeletons. *Robotics* **2020**, *9*, 16. [CrossRef]
4. Zhang, P.; Zhang, J. Motion generation for walking exoskeleton robot using multiple dynamic movement primitives sequences combined with reinforcement learning. *Robotica* **2022**, *40*, 2732–2747. [CrossRef]
5. Gherman, B.; Birlescu, I.; Plitea, N.; Carbone, G.; Tarnita, D.; Pisla, D. On the singularity-free workspace of a parallel robot for lower-limb rehabilitation. *Proc. Rom. Acad. Ser. A Math. Phys. Tech. Sci. Inf. Sci.* **2019**, *20*, 383–391.
6. Carbone, G.; Gherman, B.; Ulinici, I.; Vaida, C.; Pisla, D. Design Issues for an Inherently Safe Robotic Rehabilitation Device. In *Advances in Service and Industrial Robotics, Proceedings of the 26th International Conference on Robotics in Alpe-Adria-Danube Region, RAAD 2017, Torino, Italy, 21–23 June 2017*; Springer: Cham, Switzerland, 2018; pp. 1025–1032. [CrossRef]
7. Vaida, C.; Birlescu, I.; Pisla, A.; Ulinici, I.-M.; Tarnita, D.; Carbone, G.; Pisla, D. Systematic Design of a Parallel Robotic System for Lower Limb Rehabilitation. *IEEE Access* **2020**, *8*, 34522–34537. [CrossRef]
8. BEN Hamida, I.; Laribi, M.A.; Mlika, A.; Romdhane, L.; Zeghloul, S. Dimensional Synthesis and Performance Evaluation of Four Translational Parallel Manipulators. *Robotica* **2021**, *39*, 233–249. [CrossRef]
9. Mishra, S.K.; Kumar, C.S. Compliance modeling of a full 6-DOF series–parallel flexure-based Stewart platform-like micromanipulator. *Robotica* **2022**, *40*, 3435–3462. [CrossRef]
10. Han, Q.; Ji, A.; Jiang, N.; Hu, J.; Gorb, S.N. A climbing robot with paired claws inspired by gecko locomotion. *Robotica* **2022**, *40*, 3686–3698. [CrossRef]
11. Nekoo, S.R.; Acosta, J.; Ollero, A. Quaternion-based state-dependent differential Riccati equation for quadrotor drones: Regulation control problem in aerobatic flight. *Robotica* **2022**, *40*, 3120–3135. [CrossRef]
12. Hoffmann, T.; Prause, G. On the Regulatory Framework for Last-Mile Delivery Robots. *Machines* **2018**, *6*, 33. [CrossRef]
13. Ennaiem, F.; Chaker, A.; Arévalo, J.; Laribi, M.; Bennour, S.; Mlika, A.; Romdhane, L.; Zeghloul, S. Sensitivity Based Selection of an Optimal Cable-Driven Parallel Robot Design for Rehabilitation Purposes. *Robotics* **2021**, *10*, 7. [CrossRef]
14. Ennaiem, F.; Chaker, A.; Sandoval, J.; Mlika, A.; Romdhane, L.; Bennour, S.; Zeghloul, S.; Laribi, M.A. A hybrid cable-driven parallel robot as a solution to the limited rotational workspace issue. *Robotica* **2023**, *41*, 1–19. [CrossRef]
15. Laribi, M.A.; Carbone, G.; Zeghloul, S. On the Optimal Design of Cable Driven Parallel Robot with a Prescribed Workspace for Upper Limb Rehabilitation Tasks. *J. Bionic Eng.* **2019**, *16*, 503–513. [CrossRef]
16. Qian, S.; Zi, B.; Shang, W.-W.; Xu, Q. A Review on Cable-driven Parallel Robots. *Chin. J. Mech. Eng.* **2018**, *31*, 66. [CrossRef]
17. Malyshev, D.; Rybak, L.; Carbone, G.; Semenenko, T.; Nozdracheva, A. Optimal Design of a Parallel Manipulator for Aliquoting of Biomaterials Considering Workspace and Singularity Zones. *Appl. Sci.* **2022**, *12*, 2070. [CrossRef]
18. Čorňák, M.; Tölgyessy, M.; Hubinský, P. Innovative Collaborative Method for Interaction between a Human Operator and Robotic Manipulator Using Pointing Gestures. *Appl. Sci.* **2022**, *12*, 258. [CrossRef]
19. Pisla, D.; Tarnita, D.; Tucan, P.; Tohanean, N.; Vaida, C.; Geonea, I.D.; Bogdan, G.; Abrudan, C.; Carbone, G.; Plitea, N. A Parallel Robot with Torque Monitoring for Brachial Monoparesis Rehabilitation Tasks. *Appl. Sci.* **2021**, *11*, 9932. [CrossRef]
20. Baigunchekov, Z.; Laribi, M.A.; Carbone, G.; Mustafa, A.; Amanov, B.; Zholdassov, Y. Structural-Parametric Synthesis of the RoboMech Class Parallel Mechanism with Two Sliders. *Appl. Sci.* **2021**, *11*, 9831. [CrossRef]
21. Fomin, A.; Petelin, D.; Antonov, A.; Glazunov, V.; Ceccarelli, M. Virtual and Physical Prototyping of Reconfigurable Parallel Mechanisms with Single Actuation. *Appl. Sci.* **2021**, *11*, 7158. [CrossRef]
22. Gull, M.; Thoegersen, M.; Bengtson, S.; Mohammadi, M.; Struijk, L.A.; Moeslund, T.; Bak, T.; Bai, S. A 4-DOF Upper Limb Exoskeleton for Physical Assistance: Design, Modeling, Control and Performance Evaluation. *Appl. Sci.* **2021**, *11*, 5865. [CrossRef]
23. Ennaiem, F.; Chaker, A.; Laribi, M.; Sandoval, J.; Bennour, S.; Mlika, A.; Romdhane, L.; Zeghloul, S. Task-Based Design Approach: Development of a Planar Cable-Driven Parallel Robot for Upper Limb Rehabilitation. *Appl. Sci.* **2021**, *11*, 5635. [CrossRef]
24. Saputra, R.P.; Rakicevic, N.; Kuder, I.; Bilsdorfer, J.; Gough, A.; Dakin, A.; de Cocker, E.; Rock, S.; Harpin, R.; Kormushev, P. ResQbot 2.0: An Improved Design of a Mobile Rescue Robot with an Inflatable Neck Securing Device for Safe Casualty Extraction. *Appl. Sci.* **2021**, *11*, 5414. [CrossRef]
25. Nie, L.; Ding, H.; Ting, K.-L.; Kecskeméthy, A. Instant Center Identification of Single-Loop Multi-DOF Planar Linkage Using Virtual Link. *Appl. Sci.* **2021**, *11*, 4463. [CrossRef]
26. Huczala, D.; Kot, T.; Pfurner, M.; Heczko, D.; Oščádal, P.; Mostýn, V. Initial Estimation of Kinematic Structure of a Robotic Manipulator as an Input for Its Synthesis. *Appl. Sci.* **2021**, *11*, 3548. [CrossRef]
27. Bottin, M.; Cocuzza, S.; Massaro, M. Variable Stiffness Mechanism for the Reduction of Cutting Forces in Robotic Deburring. *Appl. Sci.* **2021**, *11*, 2883. [CrossRef]

28. Russo, M.; Ceccarelli, M.; Cafolla, D. Kinematic Modelling and Motion Analysis of a Humanoid Torso Mechanism. *Appl. Sci.* **2021**, *11*, 2607. [CrossRef]
29. Russo, M.; Chaparro-Rico, B.D.M.; Pavone, L.; Pasqua, G.; Cafolla, D. A Bioinspired Humanoid Foot Mechanism. *Appl. Sci.* **2021**, *11*, 1686. [CrossRef]