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► **To cite this version:**

Giuseppe Carbone, Med Amine Laribi. Recent Trends on Innovative Robot Designs and Approaches. Applied Sciences, 2023, 13 (3), pp.1388. 10.3390/app13031388. hal-04492516

HAL Id: hal-04492516

<https://hal.science/hal-04492516>

Submitted on 6 Mar 2024

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Recent Trends on Innovative Robot Designs and Approaches

Giuseppe Carbone ^{1,*}  and Med Amine Laribi ² 

¹ Department of Mechanical Engineering, Energy Engineering and Management, University of Calabria, 87036 Rende, Italy

² Department GMSC, Institut PPRIME, Université de Poitiers, CNRS, ENSMA, UPR 3346, 86962 Poitiers, France

* Correspondence: giuseppe.carbone@unical.it

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



Citation: Carbone, G.; Laribi, M.A. Recent Trends on Innovative Robot Designs and Approaches. *Appl. Sci.* **2023**, *13*, 1388. <https://doi.org/10.3390/app13031388>

Received: 17 January 2023

Accepted: 18 January 2023

Published: 20 January 2023



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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 ninth 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].

The Guest Editors of this Special Issue would like to express their gratitude to the authors and reviewers for their efforts and time spent in the valuable scientific contributions and useful feedback that have confirmed the high-scientific-quality of the recent trends in innovative robot design and approaches.

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

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