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Guest Editorial

Joint Special Issue: Design and Control of Responsive Robots

Robots are complex controlled dynamical systems interacting with their environment. Agile robotic systems have been penetrating almost all industrial sectors as the backbone for industrial automation, ranging from heavy duty manipulators to collaborative robots (cobots) and mobile platforms for logistics tasks. Currently, autonomous vehicles (e.g., cars, mobile delivery systems, drones, inspection, and maintenance) are entering the public sector, but also the use of surgical robots is becoming an integral part of medical treatments. In a foreseeable future, assistive robots for domestic use will become indispensable for caretaking and as exoskeletal devices providing physical support thus physically interacting with humans. Future robots need to be responsive; they must (inter)act safely, minimize the use of resources (energy, material, process-, development-, and commissioning-time), and adapt to variations in demands and environmental conditions.

Advanced robotic systems are equipped with multimodal sensory systems, and are operated with model-based and model-free control schemes. Yet, the mechanical embodiment is the starting point of any robot design. Key to a reliable design and control of such robots are holistic design approaches embracing kinematic synthesis, dynamic analysis, control, sensory perception, and adaptability. Novel mechanical design principles, combining high-fidelity kinematic and dynamic models with data-driven methods, are applied along with model-free machine learning (ML) and artificial intelligence (AI) methods. The foundation is a synergetic combination of research in mechanism theory and dynamical systems and control.

This joint special issue of the *Journal of Mechanisms and Robotics* (JMR) and the *Journal of Computational and Nonlinear Dynamics* (JCND) aims to bridge between these research fields and to bring together the latest research on robot kinematics and dynamics as well as intelligent control and data-driven methods for perception, planning, model identification, and control.

This joint special issue is a collection of 13 papers published in JMR and 10 papers published in JCND, respectively. The papers published in JMR address several of the main research topics in robot design, namely the design and control of agile and compliant robots intended for robust and safe interaction with its environment. The paper "Design, Calibration, and Control of Compliant Force-Sensing Gripping Pads for Humanoid Robots" introduces low-cost, lightweight, and compliant force-sensing gripping pads that enable smaller-sized humanoid robots to manipulate box-like objects. In "Dyno-Kinematic Leg Design for High Energy Robotic Locomotion," technique for leg design for high energy robotic locomotion is presented that encodes desired dynamic features into the mechanical design. In the paper "Emerging Gaits for a Quadrupedal Template Model with Segmented Legs," the gait stability of quadrupedal robots with articulated elastic legs is studied. The two papers "Stable Inverse Dynamics for Feedforward Control of Nonminimum-Phase Underactuated Systems" and "Experimental Safety Analysis of R-Min, an Underactuated Parallel Robot" deal with the operation of underactuated robots. In both papers, underactuation stems from the presence of compliant elements. Moreover, introducing compliance is becoming an important design approach which is the topic of the three papers "Kinetostatic Modeling of Continuum Delta Robot With Variable Curvature Continuum Joints," "Design and Modeling Framework for DexTeR: Dexterous Continuum Tensegrity Manipulator," and "Analysis of a Soft Bio-Inspired Active Actuation Model for the Design of Artificial Vocal Folds." While the first two papers address the design of robots that make use of inherently flexible components, the last paper exploits the compliance to mimic a biological system. Mechanical compliance is also the crucial feature exploited in the two papers "Flexible Long-Reach Robotic Limbs Using Tape Springs for Mobility and Manipulation" and "Control of Pneumatic Artificial Muscle Actuated Two Degrees-of-Freedom Robot Using PD-Based Pulse Width Modulation Strategy With Feed-Forward Outer Control Loop." The first proposes an innovative actuation concept while the second proposes a novel control strategy for the established concept of pneumatic artificial muscles. A bio-inspired approach to modulating the compliance of a robot is presented in "Variable Stiffness and Antagonist Actuation for Cable-Driven Manipulators Inspired by the Bird Neck." The paper "Robust Attitude Controller Design for an Uncommon Quadrotor With Big and Small Tilt Rotors" presents the modeling and robust control of a quadrotor UAV. The design innovation paper "Deep Reinforcement Learning-Based Control of Stewart Platform With Parametric Simulation in ROS and Gazebo" presents a control method that uses a dynamics simulation for training deep network to control a parallel kinematics manipulator.

The collection published in JCND has focused on assistive robots and on design and control of soft underactuated systems. The paper "Energy-Efficient Actuator Design Principles for Robotic Leg Prostheses and Exoskeletons: A Review of Series Elasticity and Backdrivability" provides an exhaustive overview of design principles for actuators used in prosthetic robotic systems. The important issue of using EMG for control of assistive devices is addressed in "Feasibility Study of Upper Limb Control Method Based on Electromyography-Angle Relation." A new design concept for a prosthetic hand is presented in the paper "Novel Kinematics of an Anthropomorphic Prosthetic Hand Allowing Lateral and Opposite Grasp With a Single Actuator." Designing and controlling robots

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to display a desired compliance is relevant in various applications. The design of inherently soft robots that can reconfigure to different shapes is presented in "Topology Design and Optimization of Modular Soft Robots Capable of Homogenous and Heterogenous Reconfiguration." Compliance control of a space robot is addressed in the paper "FSTSMC Compliance Control for Dual-Arm Space Robot with SDBD Capture Satellite Operation." The control of an underactuated flying robot with elastic attachments is presented in the paper "Design of a Sliding Mode-Adaptive PID Control for Aerial Systems with a Suspended Load Exposed to Wind Gusts." The paper "Mechanical Design, Planning, and Control for Legged Robots in Distillation Columns" addresses the design of a dedicated arm mounted on a quadrupedal robot and the control of the system when navigating in narrow environments. The paper "Delay Effects in the Dynamics of Human Controlled Towing of Vehicles" investigates the stability of a control system representing the behavior of vehicle towing. Another paper dealing with control of underactuated robots is "Variational Principles for the Trajectory Tracking Control of Underactuated Mechanical Systems," where underactuation is again due to the existence of elastic components in the robot. A crucial aspect of all simulation models, namely to calibration of existing models and the model reduction, is addressed in the paper "Using a Bayesian-Inference Approach to Calibrating Models for Simulation in Robotics."

The spectrum of contributions collected in this joint special issue by researchers from different fields is testimony to the importance of combining research in mechanical design, non-linear control, and dynamics simulation embracing modern methods from mechanism theory, non-linear dynamics, and control, as well as model-free data-driven approaches.

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