

Modelling and Control of Mechatronic and Robotic Systems

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1. Introduction

Nowadays, the modelling and control of mechatronic and robotic systems is an open and challenging field of investigation in both industry and academia [1]. The mathematical modelling of a mechanical system is indeed fundamental for the development of experimental prototypes. In particular, the kinematic model of a mechatronic or robotic system is essential for the proper definition of the path and motion law that the system has to follow during its operation. On the other hand, dynamic models are required to predict both the forces and torques acting on the system and those required by the actuators. These are ultimately useful to simulate scenarios and working conditions of interest. Furthermore, the dynamic modelling of a mechatronic or robotic system allows us to evaluate its time-dependent evolution and response under different input conditions. Indeed, a proper model can be implemented to improve the design and performance with different objectives, for instance, energy efficiency [2], and vibration reduction [3]. Furthermore, the modelling of a robotic system is essential in path and trajectory planning [4] to enhance control capabilities [5], and to increase kinematic and dynamic performance [6]. Within this framework, proper control of an automatic system is essential for successfully completing a predefined task. This is especially the case when external disturbances are present, or when dealing with flexible systems in which mechanical vibrations have to be considered.

2. Modelling and Control of Mechatronic and Robotic Systems

This Special Issue of the journal *Applied Sciences* encompasses the kinematic and dynamic modelling, analysis, design, and control of mechatronic and robotic systems, with the scope of improving their performance, as well as simulating and testing novel devices and control architectures. A broad range of disciplines are included, such as robotic manipulation, mobile systems, cable-driven robots, wearable and rehabilitation devices, variable stiffness safety-oriented mechanisms, optimization of robot performance, and energy-saving systems.

Several papers deal with control problems, applied to both robotic systems and mechanical vibrations. In paper [7], a novel sliding mode control algorithm is presented and applied for the trajectory tracking on a robotic manipulator with 3 degrees of freedom (DOF). The proposed controller runs without a precise dynamic model in the presence of uncertainties and enhances the response, fast convergence time, and accuracy of the tracking position.

The main goal of paper [8] is the design, simulation, and experimental verification of an adaptive feed-forward motion control for a hydraulic differential cylinder. The proposed solution is implemented on a hydraulic loader crane. Experimental results show the advantage of the proposed controller in reducing the cylinder position error and the adaptation to model uncertainties.

The authors in [9] present the modelling and control of a cable-suspended sling-like parallel robot for throwing a mass at a suitable time. The mass is carried at the end-effector by a gripper, which releases the mass so that it can reach a given target point. Mathematical



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models, which also account for the effect of cable elasticity, provide guidelines for planning the trajectory.

In [10], a 8-DOF integrated model of a semi-active seat suspension with a human model over a quarter is presented. A fuzzy logic-based self-tuning PID controller allows to regulate the controlled force on the basis of sprung mass velocity error and its derivative as input. Simulation results show that the semi-active seat suspension improves the ride comfort significantly by reducing the head acceleration compared to passive seat suspensions. Moreover, in [11], the authors investigate the control of the over-critical vibration of a transmission shaft system with a device named Smart Spring, an active vibration control mechanism based on piezoelectric material. Simulation results based on a model implemented in ADAMS and MATLAB show the feasibility of the approach in reducing the vibration of the shaft system.

Papers [12,13] deal respectively with trajectory optimization and with a novel kinematic directional index for industrial manipulators. In particular, in [12] a “whip-lashing” method is proposed to optimize the trajectory in order to increase the velocity of individual robot parts, thereby minimizing motion cycle times and exploiting the torque of the joints more effectively. The efficiency of the method is confirmed by simulation results on a 5-DOF RV-2AJ manipulator. In [13], a novel method is proposed for evaluating the maximum speed that a serial robot can reach with respect to both the position of the robot and its direction of motion. This approach, called Kinematic Directional Index, is experimentally applied to a SCARA robot and to an articulated robot with 6-DOF to outline their performances.

Paper [14] presents an energy-saving system based on a prefill system and a buffer system to improve the energy efficiency and the processing performance of hydraulic presses. Experimental results demonstrate that the proposed system could reduce the installed power and pressure shock, increase energy efficiency, and provide the same processing characteristics as the traditional hydraulic press.

Several papers in this Special Issue are focused on the design, modelling, and control of mobile robots and systems. In [15], a hierarchical driving force distribution and control strategy for a six-wheel unmanned ground vehicle with independent drive motors is presented to improve vehicle maneuverability and stability. In [16], authors investigate the effects of wheel slip compensation in the trajectory planning for mobile tractor-trailer robot applications. Experimental results on the prototype Epi.q show that with the proposed approach it is possible to kinematically compensate trajectories that otherwise would be subject to large lateral slip.

Papers [17,18] are focused on unmanned aerial vehicles (UAV). In [17], a high-precision attitude control is proposed for a quadrotor drone equipped with a 2-DOF robotic arm and subject to varied external disturbances. The research presented in [18] aims to develop an automatic UAV-based indoor environmental monitoring system for detecting rapid changes in the features of plants growing in greenhouses. Another research work on a mobile system included in this Special Issue is given by [19], which describes a motion planning and robust coordinated control scheme for the trajectory tracking of an underwater vehicle-manipulator system. Model uncertainties, time-varying external disturbances, payload, and sensory noises are considered and evaluated numerically.

Other works are focused on legged mobile robots. In [20], a Central Pattern Generator network controller is applied to the trot gait of a quadruped robot. The work of [21] outlines a method for the identification of optimal trajectories of quadruped robots through genetic algorithms. Furthermore, the authors in [22] illustrate an optimization of energy consumption and cost of transport using heuristic algorithms applied to a hexapod robot.

The Special Issue also includes interesting papers dealing with mobile robotic systems for planetary exploration. Paper [23] presents a general approach to endow a robot with the ability to sense the terrain being traversed. In [24], the authors propose a novel design of a robotic legged lander based on variable radius drums actuated by cables. Thanks to

this device, the robotic system can effectively decelerate with constant force during impact with ground.

Other papers are focused on robotic systems and devices that are designed to physically interact with humans for rehabilitation and safety. Paper [25] presents a novel exoskeleton mechanism for finger motion assistance. The exoskeleton is designed as a serial 2-DOF wearable mechanism that is able to guide human finger motion. The authors of paper [26] discuss the mechanical redesign of a finger rehabilitation device based on a slider-crank mechanism, starting from an existing prototype. The purpose is to obtain a portable device that can recreate the motion trajectories of a finger. Finally, paper [27] addresses the design and experimental validation of a variable stiffness safety-oriented mechanism for physical human–robot interaction.

3. Final Remarks

This Special Issue contains valuable research works focused on the modelling and control of mechatronic and robotic systems, covering a wide area of applications. This collection shows the significant research interest in these topics with a high impact and potential for future developments. We sincerely hope that this Special Issue on “*Modelling and Control of Mechatronic and Robotic Systems*” can be a valuable source of information for researchers working on these topics. We hope that you enjoy reading this Special Issue!

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