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Identification and control of nonlinear electro-mechanical systems

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EDITORIAL

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Introduction

Electro-mechanical systems are systems composed of both electrical and mechanical parts. They include motors, robots, cranes, compactors, electro-mechanical positioning systems, nanopositioning systems, and piezoelectric actuators, amongst others. As a consequence, mechanical and electrical engineering communities encompass a variety of fields such as robotics, mechatronics, electrotechnics, electronics, and power engineering, all of which can be considered a part of an over-arching electro-mechanical community.

Within the electro-mechanical community, system identification refers to the whole process of identifying the most appropriate model form and estimating the parameters of this model from measured input/output data or from a combination of such data and prior knowledge. Dynamical models obtained in this manner are useful for tasks such as analysing the system properties (e.g. identification of nonlinear friction models); performing simulation experiments; and control system design (e.g. model-based control, predictive control, sliding-mode control).

Such dynamical models are usually formulated in terms of differential equations, or transfer functions in the differential operator, because the physical laws on which the models are based are normally synthesised in terms of differential equation relationships based on natural laws, such as Newton's laws, Ohm's law, Kirchhoff's relations and Maxwell's equations. It is not surprising, therefore, that most electro-mechanical engineering theory and practice is based on continuous-time models. Electro-mechanical system control has similar objectives to most automatic control systems, i.e. to control the system so that its output follows a desired reference, which may be a fixed or changing value (a set point or trajectory).

Despite the similarities between the automatic control and electro-mechanical engineering communities, some important differences remain. For example, within the electro-mechanical community, the identification and/or control methodology is mostly devoted to specific real-world systems rather than to general systems. The theoretical aspects of methodology, such as the statistical efficiency of the model parameter estimates or the optimality of the control system, are addressed much less often, whereas these are prolific topics in the automatic control community, where many papers are based on theoretical analysis and results. The electro-mechanical community, on the other hand, is often more reluctant to make general theoretical assumptions, tending to mistrust such generalisations when dealing with real-world systems and producing experimental results. And finally, both nonlinearity and high dimensionality are often unavoidable in electro-mechanical systems and so the consideration of such factors is much more prevalent in the electro-mechanical engineering community.

Fortunately, there is evidence that these differences between the two communities are growing less and the present special issue is intended to encourage still greater cross-fertilisation between the communities, which we believe will result in advantages to both. It presents papers dealing with examples that are concerned with the identification and control of various different electro-mechanical systems; and examples that help to reveal the capabilities of current identification/control methods when they are applied to challenging, real-world applications.

In the review of the content below, the papers have been separated into those that are involved with the implementation of the proposed methodology on a real electro-mechanical system, which are considered first, and then those that use computer simulation to demonstrate the feasibility of the proposed methodology.

Content of the special issue

The first paper by Alexandre Janot, Peter C. Young and Maxime Gautier addresses the topic of electro-mechanical systems identification, with an application in robotics, by describing a new alternative but related approach that exploits the state-dependent parameter (SDP) method of nonlinear model estimation and compares its performance with that of the standard approach. The next paper by Allahyar Montazeri, Craig West, Stephen D. Monk and James Taylor concerns the problem of dynamic modelling and parameter estimation for a seven degree of freedom hydraulic manipulator. In order to estimate the physical parameters of the complex robotic arm, the method involves the use of a multi-objective genetic algorithm and the methodology is evaluated using both simulated and experimental data. The paper by Ryad Chellal, Loic Cuvillon and Edouard Laroche presents methodologies for the identification and control of six-degrees of freedom (6-DoF) cable-driven parallel robots (CDPRs). These are evaluated both by simulations and experimentally on a redundant 6-DoF INCA 6D CDPR with eight cables, equipped with a motion-tracking system. Angel Valera, Miguel Diaz-Rodriguez, Marina Valles, Ernesto Oliver, Vicente Mata and Alvaro Page describe the design of a model-based control for an electro-mechanical lower-limb rehabilitation system based on a parallel kinematic mechanism. The contribution by Patricio Ordaz and Mario Ordaz is concerned with the problem of stabilising an inertial coupling electro-mechanical system using nonlinear time-varying controllers. An indirect modelling framework that deals with identification of systems where the input is partially or fully unknown is presented in the contribution by Jonas Linder and Martin Enqvist. Then, Frank Boeren, Dennis Bruijnen and Tom Oomen present a new algorithm that combines unbiased parameter estimates with optimal accuracy in terms of variance and apply this to an industrial nanopositioning system. The paper by Lukasz Ryba, Jakub Dokoupil, Alina Voda, and Gildas Besancon considers a novel adaptive approach for hysteresis compensation applied to a piezoelectric actuator in one axis of an STM-like lab-made micro-nanopositioning platform and provides experimental results that demonstrate the relevance of their approach. The contribution of Fabrice Demourant and Charles Poussot-Vassal introduces an innovative method for identifying models using a modified frequency-domain subspace method and illustrates this with results of experiments on the identification and control of the gust disturbance over an aircraft wing. Victor G. Lopez, Edgar N. Sanchez, Alma Y. Alanis and Jorge D. Rios introduce and experimentally validate a discrete-time neural inverse optimal control system used to control the position of a three-phase linear induction motor (LIM).

The paper by Alexey Bobtsov, Dmitry Bazylev, Anton Pyrkin, Stanislav Aranovskiy and Romeo Ortega focuses on a new rotor position observer for surface-mounted permanent magnet synchronous motors and suggest, using realistic simulation results, that this should result in significant performance improvement. On a similar topic, Jean-François Massieu, Philippe Dorléans and Vincent Van Assche demonstrate the use of a specific time-varying gain in a sampled-data observer for induction motors. The paper by Andrea Tilli, Christian Conficoni and Ahmad Hashemi addresses the problem of controlling stator/rotor currents in a doubly fed induction generator under faulty line voltage and demonstrates this through realistic simulations that exploit both feedforward and feedback control. Then, Godpromesse Kenné, Armel Simo Fotso and Françoise Lamnabhi-Lagarrigue present a new hybrid method that combines a radial basis function (RBF) neural network with a sliding-mode technique and demonstrate the effectiveness and feasibility of the proposed approach. The penultimate contribution by Jun Qian, Madiha Nadri and Pascal Dufour deals with a closed-loop optimal experimental design for an online parameter identification approach for nonlinear dynamic systems and shows that the proposed algorithm is capable of identifying all of the unknown parameters while keeping the closed-loop system stable. Finally, the last paper by Robin P. Guan, Branko Ristic, Liuping Wang, Bill Moran and Rob Evans presents the merits of the Doppler radar compared to other existing sensors used for robot navigation.

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