An Introduction to the Special Issue on Advanced Control Methods: Theory and Application

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The special Issue "Advanced Control Methods: Theory and Application" intents to collect and present high-erudite papers aiming theoretical as well as practical matters dealing with complex systems and advanced control methods designated for their steering.

From the system theory point of view, most technological processes belong to the class of nonlinear lumped or distributed parameter systems. It is well known that control of such processes often represents a very complex problem. The control problems are due to the process nonlinearities, its distributed nature, and, high sensitivity of the state and output variables to input changes. In addition, the dynamic characteristics may exhibit a varying sign of the gain in various operating points, time delay as well as non-minimum phase behaviour. Evidently, processes with such properties are hardly controllable by conventional control methods based on the usage of controllers with fixed parameters. Their effective control then requires application of advanced methods. These methods have been developed in the past decades and are based on different principles. Generally, none of these methods is universal, and, for control of a process the most appropriate is only one of them. From this perspective, a research of various applications is useful and desirable.

The aim of this special issue is to highlight greatly significant recent developments on the topics of analysis and control of such systems, covering the scale from purely theoretical articles to real-life applications.

The performance of dynamic property of the mount is influenced by multiple factors and strongly depends on the working conditions. This means that the modal parameters of powertrain mounting system would make changes under different operating conditions. A novel approach to simulate the actual working condition is proposed in the testing of dynamic stiffness in the paper by I. Jin, J. Zhang and X. Guan entitled "Theoretical Calculation and Experimental Analysis of the Rigid Body Modes of Powertrain Mounting System". Then the mechanical model of powertrain mounting system based on dynamic stiffness is established in this paper as well. In order to examine the rationality and accuracy of the computational model based on dynamic stiffness; experimental modal analysis is performed by multiple means and methods in this paper. Through the contrast analysis, advantages and disadvantages of these methods are illustrated and it is shown that using the method of Operational Modal Analysis could obtain more accurate and more reliable results. Based on the experimental and evaluation results, it is shown that there is smaller relative error and higher fitting degree between the calculation results based on dynamic stiffness and the results obtained from operational modal analysis. Moreover, the proposed method also enjoys satisfactory consistency with the actual working condition.

The paper "Feedforward Model Based Active Force Control of Mobile Manipulator using MATLAB and MD Adams" by the authors S. Abdulah, M. Mailah and C. T. H. Hing highlights the potentials of using a feedforward model based Active Force Control (AFC) as a disturbance rejection scheme in the motion control of a mobile manipulator (MM). The AFC part creates a force or torque feedback within the dynamic system to allow for the compensation of the sudden disturbance introduced into the system prior to relaying the signal to the conventional outer-loop position controller employing a resolved acceleration control (RAC) configuration, thereby increasing the robustness of the MM system. The proposed AFC-based model also shows a faster computational performance by manipulating the estimated inertia matrix (***IN***) of the system instead of considering the entire system dynamic model. A feedforward element in the form of a simplified model of the dynamic system is implemented to complement the ***IN*** for a better trajectory tracking performance of the system. The simulation was performed and the results were compared with the computed torque control (CTC) with RAC scheme to benchmark the performance and robustness of the AFC-based counterpart. The MM consists of a skid steering four wheel nonholonomic mobile platform with a three degree-of-freedom (DOF) articulated manipulator attached on top. With the proposed controller incorporated into the system, the tracking performance of the MM is considerably enhanced with increased workspace capacity and better operation dexterity.

The majority of processes met in the industrial practice have stochastic characteristics and eventually they embody non-linear behaviour. Traditional controllers with fixed parameters are often unsuitable for such processes because their parameters change. The changes of process parameters are caused by changes in the manufacturing process, in the nature of the input materials, fuel, machinery use (wear) etc. Fixed controllers cannot deal with this. One possible alternative for improving the quality of control for such processes is the use of adaptive control systems. Different approaches were proposed and utilized. One successful approach is represented by self-tuning controller (STC). This approach is also called system with indirect adaptation (with direct identification). The main idea of an STC is based on the combination of a recursive identification procedure and a selected controller synthesis. Presently, most of the STCs are based on the Certainty Equivalence (CE) Principle, which is only suboptimal. One of the possibilities to improve the quality of these adaptive control methods is usage of an Adaptive Dual Control (the bicriterial approach). In the paper “Self-tuning Control of Non-linear Servomotor: Standard Versus Dual Approach” by V. Bobál, P. Chalupa, P. Dostál and M. Kubalčík, the bicriterial approach is verified and compared with some other adaptive control approaches based on the CE Principle by the real-time control of a highly non-linear laboratory model, the DR300 Speed Control with Variable Load.

Many processes are affected by external disturbances caused by the variation of variables that can be measured. The aim of the paper by M. Kubalčík and V. Bobál entitled “Control Algorithms with Suppression of Measurable Disturbances: Comparison of Two Methods” is to compare two control strategies which are suitable for rejection of measurable disturbances. The first method which can successfully handle known measurable disturbances is model predictive control (MPC). Known disturbances can be taken explicitly into account in predictive control. Two different approaches to computation of multi–step–ahead predictions incorporating known measurable disturbances into prediction equations are proposed. The second control algorithm is designed using polynomial theory developed for linear controlled systems. Both methods are based on a same model of a controlled process. Simulation results are also included and quality of control achieved by both methods is compared and discussed.

P. Dostál, V. Bobál and J. Vojtěšek present an effective procedure for control design of multi input – multi output nonlinear processes in their contribution “Control Design of a Nonlinear Multivariable Proces”. The procedure is based on an approximation of a nonlinear model of the process by a continuous-time external linear model in the form of the left polynomial matrix fraction. The parameters of the continuous-time external linear model are recursively estimated either by a direct method or through an external delta model. The control system structure with two feedback controllers is used. The controllers are derived using the explicit pole assignment method. The control is simulated on the nonlinear model of two conic liquid tanks in series.

The aim of the paper “On a Controller Parameterization for Infinite-Dimensional Feedback Systems Based on the Desired Overshoot” by L. Pekař is to introduce, in detail, a novel approach for tuning of anisochronic single-input single-output controllers for infinite-dimensional feedback control systems. A class of Linear Time-Invariant Time Delay Systems (LTI TDSs) is taken as a typical representative of infinite-dimensional systems. Control design to obtain the eventual controller structure is made in the special ring of quasipolynomial meromorphic functions (R_{MS}). The use of this algebraic approach with a simple feedback loop for unstable or integrating systems leads to infinite-dimensional (delayed) controllers as well as the whole feedback loop. A natural task is to set tunable controller parameters in order to form the crucial area of the infinite closed-loop spectrum. It is worth noting that not only poles yet also zeros are taken into account. The prescribed positions of the right-most reference-to-output poles and zeros are given on the basis of the desired overshoot for a simple finite-dimensional matching model the detailed analysis of which is provided. The dominant poles and zeros are shifted to the prescribed positions using the Quasi-Continuous Shifting Algorithm (QCSA) followed by the use of an advanced optimization algorithm. The whole methodology is called the Pole-Placement Shifting based controller tuning Algorithm (PPSA). The PPSA is demonstrated on the setting of parameters of delayed controller for an unstable time delay plant of a skater on the controlled swaying bow. This example, however, shows a treachery of the algorithm and a natural feature of an infinite-dimensional system – namely, that its spectrum or even its dominant part cannot be placed arbitrarily. Advantages and drawback as well as possible modification of the algorithm are also discussed.

Finally, the closing paper “Pole-placement and LQ Hybrid Adaptive Control Applied Isothermal Continuous Stirred Tank Reactor” deals with simulation experiments on the nonlinear system represented by the isothermal continuous stirred tank reactor. The authors, J. Vojtěšek and P. Dostál, introduce a derived mathematical model from the material balances inside the reactor as first and then the steady-state and the dynamic analyses were performed on this model. As a result of these studies, the optimal working point and the choice of the external linear model for the identification will be obtained. The spectral factorization with pole-placement method and linear-quadratic approach were employed in the controller design and computation. Both types of adaptive controllers have parameters for tuning of the output response. Moreover, controllers have satisfied basic control requirements such as the stability, the reference signal tracking and the disturbance attenuation.

This special issue is composed of papers by mathematicians, system- and control-engineers as well as scientists who study various problems in analysis and control of very complex dynamical systems including nonlinear, distributed or time delay systems. We are looking forward to hearing reactions and comments from you, the reader, as you engage in your design struggles and successes as well. We hope this special issue can support the designing of new communities of learners, engineers and scientists as well. We dare to claim that this issue can contribute a little drop into the ocean of science.