Preface to Vol 2, No 3 of the Journal of Intelligent Industrial Systems

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The new issue of the Journal of Intelligent Industrial Systems presents research findings in significant areas of industrial systems technology, that is modelling, control and fault diagnosis. In the new issue, the problem of controller design for industrial systems is solved in several nontrivial cases: (i) under uncertainty about the measurements of the system's state vector elements as well as under uncertainty about disturbance inputs which are exerted on the system (ii) under uncertainty about the entire dynamical model of the system jointly with underactuation and (iii) under PDE dynamics. Differential flatness theory is the main constituent of the control approaches developed for treating the aforementioned control problems (i) to (iii). In all cases the global asymptotic stability of the control loop is demonstrated.

Moreover, in this issue the problems of probabilistic modelling and neural networks-based fault diagnosis in industrial systems are also explored. It is shown that probabilistic modelling, that is description of the system's model through known statistical distributions can be used in certain cases for representing key features of industrial systems. Alternatively it is proposed to apply non-parametric estimators of the neural network type so as to extract the model of industrial systems out of data sets. Moreover, it is proposed to exploit neural networks for accomplishing fault diagnosis tasks. In such an approach the neural network is used for assigning the industrial systems' output to fault classes.

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In article “Controller design for AGVs and Kalman Filter-based compensation of disturbance forces and torques” by G. Rigatos, P. Siano and G. Ingenito, a controller is developed for autonomous 4-wheeled ground vehicles making use of differential flatness theory. Using a 3-DOF nonlinear model of the vehicle's dynamics and through the application of differential flatness theory an equivalent model in linear canonical (Brunovsky) form is obtained. For the latter model a state feedback controller is developed that enables accurate tracking of velocity setpoints. Moreover, it is shown that with the use of Kalman Filtering it is possible to dynamically estimate the disturbances due to unknown forces and torques exerted on the vehicle. The processing of velocity measurements (provided by a small number of on-board sensors) through a Kalman Filter which has been redesigned in the form of a disturbance observer results in accurate identification of external disturbances affecting the vehicle's dynamic model. By including in the vehicle's controller an additional term that compensates for the estimated disturbance forces, the vehicle's motion characteristics remain unchanged. Numerical simulation confirms the efficiency of both the proposed controller and of the disturbance forces estimator.

In article “Differential flatness theory-based adaptive fuzzy control of underactuated nonlinear systems” by G. Rigatos and P. Siano, an adaptive fuzzy controller is designed for a class of underactuated nonlinear robotic manipulators, under the constraint that the system's model is unknown. The control algorithm aims at satisfying the H_∞ tracking performance criterion, which means that the influence of the modeling errors and the external disturbances on the tracking error is attenuated to an arbitrary desirable level. After transforming the robotic system into the canonical form, the resulting control inputs are shown to contain nonlinear elements which depend on the system's parameters.

The nonlinear terms which appear in the control inputs are approximated with the use of neuro-fuzzy networks. It is shown that a suitable learning law can be defined for the aforementioned neuro-fuzzy approximators so as to preserve the closed-loop system stability. With the use of Lyapunov stability analysis it is proven that the proposed adaptive fuzzy control scheme results in H_∞ tracking performance. The efficiency of the proposed adaptive fuzzy control scheme is checked in the case of a 2-DOF planar robotic manipulator that has the structure of a closed-chain mechanism.

In article “Differential flatness properties and feedback control of the Fokker-Planck PDE” by G. Rigatos, P. Siano and A. Melkikh, the problem of feedback control of the Fokker-Planck PDE is analysed. It is shown that the procedure for numerical solution of the Fokker-Planck PDE results into a set of nonlinear ordinary differential equations (ODEs) and an associated state equations model. For the local subsystems, into which a Fokker-Planck PDE is decomposed, it becomes possible to apply boundary-based feedback control. The controller design proceeds by showing that the state-space model of the Fokker-Planck PDE stands for a differentially flat system. Next, for each subsystem which is related to a nonlinear ODE, a virtual control input is computed, that can invert the subsystem’s dynamics and can eliminate the subsystem’s tracking error. From the last row of the state-space description, the control input (boundary condition) that is actually applied to the Fokker-Planck PDE system is found. This control input contains recursively all virtual control inputs which were computed for the individual ODE subsystems associated with the previous rows of the state-space equation. Thus, by tracing the rows of the state-space model backwards, at each iteration of the control algorithm, one can finally obtain the control input that should be applied to the Fokker-Planck PDE system so as to assure that all its state variables will converge to the desirable setpoints.

In article by “Probabilistic battery design based upon accelerated life tests” by E. Chiodo, D. Lauria, N. Andrenacci and G. Pedè, a probabilistic battery design method is introduced, focusing on lithium-ion batteries, based upon battery lifetime and related economical aspects. The method takes into account the dependence of battery lifetime on different parameters, such as design maximum specific power and operating environment. The method relies on a large set of experimental measurements, in particular accelerated life tests. In addition, the randomness of the above parameters in real operating conditions is considered in the paper. Based on available experimental data, the lifetime probability distribution of these batteries has been estimated by means of a Weibull distribution model. More specifically, after a thorough statistical data analysis, a probabilistic method for battery design is proposed which ensures the minimization

of a suitable cost function which has the expected lifetime as a basic input. The method allows to guarantee the required robustness design against the random variations in specific power experienced by a lithium ion battery designed for a small electric bus operating in public transport service.

In article “An intelligent approach to predict vibration rate in a real gas turbine” by A. Shirazi, M. Hatami, M. Yaghoobi, and S. Chabok, a neural networks-based method for fault diagnosis in bearings of gas turbines is developed. The vibration rate of a real double shaft 25 megawatt gas turbine, is modelled using a multi-layer perceptron neural network and cuckoo optimization algorithm. A real dataset is used for training the neural network consisting of samples which are collected throughout a year from a gas turbine in a gas pressure booster station. Evaluation of predicted vibration rates was performed by using various performance indexes. The efficiency of the proposed modelling approach, comparing for instance to radial basis function networks and standard multi-layer perceptron neural networks, has been demonstrated. The proposed neural modelling method for the gas turbine can be also used for online prediction of the turbine’s vibrations rate without requiring a data set-based training phase.

In article “Taxonomy of induction motor mechanical fault based on time-domain vibration signals by multiclass SVM classifiers” by P. Gangsar and R. Tiwari, a method for fault diagnosis in induction motors is developed making use of multiclass support vector machine (SVM) algorithms based on time domain vibration signals. The proposed approach aims at classifying mechanical faults of induction motors, such as bearing fault, unbalanced rotor, bowed rotor and rotor misalignment at different rotational speeds and in various loading conditions. An induction motor test laboratory prototype was used to generate vibration signals related with mechanical faults. For more effective fault diagnosis, one-versus-one multiclass SVM approach with the Gaussian-radial basis function (RBF) kernel has been used. For the fault classification, firstly optimum statistical features from higher statistical moments have been selected. Also the selection of SVM kernel parameters, numbers of feature datasets and optimum ratio of training-to-testing data have been performed. The SVM classifier is trained and tested at using the data measured from the machine at the aforementioned rotation speeds. There has been also testing of the fault diagnosis method at intermediate rotational speeds for which measured data were not available. Better classification results have been obtained for high rotational speeds and large loads of the IM machine.

As a concluding remark about the new issue of the Journal of Intelligent Industrial systems it can be noted that the handling of uncertainty and unknown dynamics remains a key issue for performing modelling, control, and fault

diagnosis in industrial systems. Control jointly with state estimation and system identification methods can assure the reliable functioning of industrial systems when a precise mathematical model about them is missing. Moreover, parametric probabilistic techniques as well as nonparametric estimation methods allow the solution of the modelling problem for industrial systems and also permit their efficient condition monitoring and the diagnosis of faults. The

methods analyzed in this issue can contribute to the more reliable and safe functioning of industrial systems and give an insight to a wide research area which is worth of further exploration.

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Editors-in-Chief