PREFACE

Today's automatic control systems are of high degrees of integration, complexity, embedding and networking of heterogeneous entities. This trend is driven by the industrial needs for achieving new technical performance and meeting additional performance demands. A most critical and important issue surrounding the design and operation of complex automatic systems is the application of Fault Detection and Isolation and Fault-Tolerant Control (FDI/FTC) technology, aiming at guaranteeing high system performance over a wide operating range and meeting the requirements on system safety, reliability, availability and dependability. Although FDI/FTC has been developed in the framework of systems and control theories, it is mainly dedicated to the individual solutions for fault detection, diagnosis and fault tolerant control at the real time level. In order to cope with the industrial trends and demands, an FDI/FTC framework should be established in the context of fault management, health awareness and self-healing, and on a multi-disciplinary fundament with control, communication and computer sciences as its core. It is with these ideas in mind that the first edition of the Conference on *Control and Fault-Tolerant Systems, SysTol'10*, held in Nice, France, on 6–8 October 2010, was organized. The focus of the Conference was on new developments and applications of FDI/FTC and gathered the best international specialists. This special issue of *AMCS* is built around 14 selected contributions from this Conference, for which the authors were required to propose extended and enhanced versions of their work, and 3 complementary regular papers whose topics lie in this research area.

The design of a fault tolerant control law frequently necessitates detection, isolation and identification of faults, and this issue includes contributions in this area. The paper by H. Jamouli, M.A. El Hail and D. Sauter revisits the seminal work of Willsky and Jones about the generalized likelihood ratio test for fault detection. The proposed extension concerns the diagnosis of multiple sequential faults and is based on a reference model updated on line after the detection and isolation of each fault. The proposed strategy can be easily integrated in reconfigurable fault tolerant control systems. The paper by D. Uciński treats the problem of fault detection for processes described by partial differential equations. It is based on the maximization of the power of a parametric hypothesis test which checks whether or not system parameters have nominal values. Based on performance criteria related to the estimated parameters, a sensor network scheduling strategy consisting in selection of a subset from among a finite set of potential sensor location is proposed.

Graph theory and graphical methods have been used for a long time for highlighting structural properties of systems which can be exploited in the fault diagnosis framework. Among these tools, signed directed graphs are able to show the causal relationships between process variables. Establishing this type of model is difficult and the latter needs to be validated. The paper by F. Yang, S.L. Shah and D. Xiao proposes two validation methods based respectively on cross-correlation analysis and entropy transfer. An industrial case study illustrates the proposed methods. Graph-theoretic methods are also used in the paper by M. Ungermann, J. Lunze and D. Schwarzmann. It concerns the generation of test signals used in service diagnosis. This kind of approach can be likened to an active diagnosis method. Isolability of faults is analyzed with respect to system operating conditions.

A general multi-purpose fault tolerant control method is described in the paper by H.H. Niemann. A control architecture based on the Youla–Jabr–Bongiorno–Kucera (YJBK) parameterization is described. Based on this controller architecture the closed-loop system is analyzed by using the dual YJBK transfer function. This analysis is made with respect to closed-loop stability, fault diagnosis and system monitoring, and leads to redesign and controller reconfiguration. The paper by H. Yang, B. Jiang, V. Cocquempot and L. Lu follows the same objective. The proposed strategy relies on the assumption that the plant model belongs to a pre-specified set of models (nominal and faulty situations), and that there exists a finite family of candidate controllers such that the faulty system is stabilized when controlled by at least one of those candidate controllers. The authors then propose to sequentially switch controllers until the appropriate one is found. As a consequence, fault isolation boils down to finding the correct controller, which can be directly applied once selected.

Historically, from the point of view of practical applications, a significant amount of research on fault-tolerant control systems has been motivated by aircraft flight control system designs, with the goal of ensuring a safe landing in the event of severe faults in an aircraft. Although the fault-tolerant control problem has begun to draw more and more attention in a wider range of industrial and academic communities, aeronautic and aerospace applications continue to be in demand of this kind of research. Four papers cover fault tolerance and fault recovery in this application field. The first one, by X. Olive, presents the state of the art in fault management for autonomous satellites and describes the actual approaches implemented on an attitude and orbit control system of telecommunication satellites. The second paper, by C. Edwards, H. Alwi and C.P. Tan, explains how the sliding mode methods employing nonlinear control/injection signals to force the system trajectories to attain in finite time a motion along a surface in the state-space can be exploited for both fault detection and fault tolerant control. The proposed FTC scheme is illustrated on a motion flight simulator configured to represent a post-failure aircraft. The third work, by T. Jain, J.J. Yamé and D. Sauter, exploits the behavioral system theory. The suggested fault accommodation scheme relies on the design of an appropriate behavioral interconnection. The proposed fault tolerance mechanism is illustrated on an aircraft during the landing phase. Finally, the fourth paper, by P. Weber, B. Boussaid, A. Khelassi, D. Theilliol and C. Aubrun, develops a reconfigured control allocation strategy based on the on-line re-estimation of actuator reliability. It consists in modifying the reference according to the system constraints, which become stricter after actuator fault occurrence. The proposed approach is illustrated by a flight control application.

The quality of model-based FDI/FTC heavily relies on the ability of the model considered to describe the actual behavior of the system to be monitored. The use of linear models being limited, research has been directed towards the use of nonlinear models. Although they are generally more difficult to handle, certain classes of nonlinear models are suitable for the implementation of methods developed in the context of linear models. It is particularly the case for Linear Parameter Varying (LPV) and Takagi–Sugeno (T–S) models. The paper by R.J. Patton, L. Chen and S. Klinkhieo proposes to combine a robust fault estimator based on an LPV model within an adaptive FTC fault compensation system. This approach is particularly suitable for mechanical/mechatronic systems with friction phenomena. In that case, the friction forces, regarded as actuator faults, are estimated and their effect is compensated within a polytope controller system, yielding a robust form of active FTC that is easy to apply. The proposed design strategy is illustrated using a nonlinear two-link manipulator system with friction forces acting simultaneously at each joint. The paper by S. Montes de Oca, V. Puig, M. Witczak and Ł. Dziekan also uses polytopic LPV techniques to design an actuator fault tolerant controller. The proposed approach implements an unknown input observer and a state feedback controller. Its performance is assessed on a laboratory model experiment with a two degree of freedom helicopter. Fault diagnosis and fault tolerant control methods can also play an important role in improving the performances of road vehicles. The paper by P. Gáspár, Z. Szabó and J. Bokor presents a supervisory decentralized architecture for the design and development of reconfigurable and fault-tolerant control systems in road vehicles. The proposed design is based on an LPV method that uses monitored scheduling variables during the operation of the vehicle.

Two papers of this issue describe systems with nonlinear behavior using Takagi–Sugeno models. The first one, by D. Xu, B. Jiang and P. Shi, deals with the problem of actuator fault estimation. A robust sliding mode observer is designed based on a T–S model, and an inverse system method is used to estimate the actuator fault. In the same context, the second paper, by D. Ichalal, B. Marx, J. Ragot and D. Maquin, proposes actuator fault tolerant control. The suggested methods require simultaneous estimation of the system state and actuator fault. To this end, two methods are proposed: the first one extends to the nonlinear case a previously developed adaptive fast state and fault observer, while the second implements a proportional integral observer. Academic simulation examples illustrate these approaches.

The model predictive control method, which consists in solving on-line a finite horizon open-loop optimal control problem subject to system dynamics and constraints involving states and controls, has demonstrated its efficiency in a very wide range of applications. Naturally, this approach has been investigated in the FDI/FTC framework. The paper by A. Yetendje, M.M. Seron and J.A. De Doná exploits this method to design a fault tolerant output feedback controller that ensures robust closed-loop exponential stability and good performance in the fault-free case and under the occurrence of abrupt sensor faults. Similarly, K. Patan and J. Korbicz propose the implementation of a predictive controller by means of a recurrent neural network which acts as a one-step ahead predictor. Based on the knowledge of *a priori* faulty scenarios, a fault detection and compensation module is designed using that predictor. The proposed strategy is applied to a boiler unit.

We believe that this special issue gives a valuable overview of actual results in the fault diagnosis and fault tolerance field and will encourage the development of enhanced theories and applications. Finally, we would like to thank all the authors and reviewers who contributed to this issue.

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