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EDITORIAL

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# Fault diagnosis and fault-tolerant control in aerospace systems

## 1 | INTRODUCTION

Modern technological and safety-critical systems rely on sophisticated control solutions to meet increased performance demands in faulty conditions and in terms of reliability and safety requirements. A conventional feedback control design for a complex system may give unsatisfactory performance or even instability, in the event of malfunctions in actuators, sensors, or other system components. To overcome this limitation, new approaches to control system design have been developed in order to tolerate component malfunctions while maintaining desirable stability and performance properties. This feature is particularly important for safety-critical systems, such as aircraft and spacecraft. In such plants, the consequences of a minor (abrupt or incipient) fault in a system component can be catastrophic. Therefore, the demand on reliability, safety, availability, and fault tolerance is generally high. It is necessary to design control strategies that are capable of tolerating potential faults in order to improve reliability, safety, and availability while providing desirable performances. These types of control systems are known as fault-tolerant control systems. In more detail, they consist of control systems possessing the ability to accommodate component faults automatically. They are also capable of maintaining overall system stability and acceptable performance in the event of such faults. In other words, a closed-loop control system that can tolerate component malfunctions, while maintaining desirable performance and stability properties is considered to be a fault-tolerant control system.[1]

On the other hand, over the last four decades, the growing demand for safety, reliability, maintainability, and survivability in technical systems has encouraged significant research in fault detection and diagnosis, resulting in the development of many solutions. Note that, in the literature, fault detection and isolation or fault detection and identification (estimation) are often used. In fault-tolerant control system designs, fault identification (ie, estimation) is important; therefore, the fault detection and diagnosis tasks are mainly considered to highlight the requirement of fault reconstruction. On a parallel path, research on reconfigurable fault-tolerant control systems has increased progressively since the initial research on restructurable control and self-repairing flight control systems began in the early 1970s. More recently, fault-tolerant control has attracted more and more attention in both industry and academia due to increased demands for safety, high system performance, productivity, and operating efficiency in a wider engineering applications, not limited to traditional safety-critical systems.[2,3]

From the beginning of 1980, several milestones were presented in the literature. In particular, apart from the triennial IFAC Symposium on Fault Detection, Supervision and Safety for Technical Process (SAFEPROCESS) which started in 1991, in 2010, the first International Conference on Control and Fault-Tolerant Systems (SysToL'10) was a success and demonstrated the demand for establishing a permanent scientific forum in the general area of system monitoring, fault diagnosis, and fault-tolerant control. The second International Conference on Control and Fault Tolerant Systems (SysToL'13), through its technical program, provided a unique opportunity for the academic and industrial communities to formulate new challenges, share solutions, and discuss future research directions. Presentations of theoretical results accompanied by practice related experiments were encouraged, and the best contributions have been selected for this special issue from the latest SysToL'16 Conference held in Barcelona, Spain, in September 7-9, 2016.

Historically, from the point of view of practical application, a significant amount of research on fault-tolerant control systems was motivated by aircraft flight control system designs. The key point was to provide fault accommodation in the event of severe faults in the aircraft. Such effort was also stimulated partly by two commercial aircraft accidents in the late 1970s, particularly involving Delta Flight 1080 (April 12, 1977) and American Airlines DC-10, in Chicago. It is thus evident why the fault-tolerant control problem began to draw more and more attention in a wider range of academic and application communities. Therefore, obvious applications include aerospace and aircraft industries.[4]

This special issue highlights that, maybe due to historical reasons and the complexity of the problem, most of the research on fault diagnosis and fault-tolerant control was carried out as a two separate tasks. More specifically, most of the fault diagnosis techniques are developed as a diagnostic or monitoring tool, rather than an integral part of fault-tolerant control. As a result, some existing fault detection methods may not satisfy the need of controller reconfiguration. On the other hand, most of the research on reconfigurable controls is carried out assuming the availability of a perfect fault diagnosis. Little attention has been paid to analysis and design with the overall system structure and interaction between fault diagnosis and fault-tolerant control. From the viewpoint of fault-tolerant control design, what are the needs and requirements for fault diagnosis? How to design the fault diagnosis and fault-tolerant control in an integrated manner for online and real-time applications? Many challenging topics, which are analyzed by the contributions to this special issue properly selected from the SysToL'16 Conference, still remain open for further research and development.[2,3]

One of the motivations of this special issue is to provide an overview of recent developments in fault-tolerant control systems, with application to aerospace systems. At the same time, this special issue aims to present some challenging open problems for future research. It is the proponents' hope that this special issue could provide some useful information to researchers and practitioners in the field in order to facilitate further development of this important area.

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