Preface

With the development technology, modern control systems, such as flight control systems, become more and more complex and involve an increasing number of actuators and sensors. These physical components may become faulty which may cause system performance deterioration, may lead to instability that can further produce catastrophic accidents. In order to improve system reliability and to guarantee system stability in all situations, many effective fault-tolerant control (FTC) approaches including fault diagnosis (FD) have been proposed in literature. Among the faults occurred in the controlled systems, the actuator faults and sensor faults are common. Up to now, for the actuator faults and sensor faults, many relevant results have been obtained in the literature. However, these theoretical studies are not perfect, and there still are problems of actuator faults and sensor faults, which are worth to be further deeply investigated due to its academic meaning as well as its practical one:

1. **Motivation from academic research**

   Infinite-number-integrated-fault model. Most of the existing works on FD and FTC in literature only considered bias faults, while gain faults have not attracted enough attention. From the theoretical point of view, it is possible that bias and gain faults simultaneously occur in systems. Furthermore, the fault number may be infinite. Hence, it is necessary to propose a novel general fault model, which can describe infinite-number-faults and deal with time-varying bias fault and gain fault.

   Singularity of fault-tolerant controller. In order to compensate for actuator gain fault, the denominator of the fault-tolerant control input contains the estimation of the gain fault. If the denominator is equal to zero, a controller singularity occurs. Hence, a novel FTC scheme must be designed to avoid the controller's singularity.

   FTC against un-model fault. The actuator (sensor) bias and gain faults have an affine-like appearance of the control input (system output). The un-modeled faults have no traditional affine appearance. Furthermore, the existing results on the bias and gain faults in literature cannot be directly extended to FD and FTC against the un-modeled faults. Therefore, it is necessary to design novel FTC algorithm for the un-modeled faults.

Computation complexity in backstepping design procedure. To control including FTC for the unknown nonlinear systems in or transformable to parameter strict-feedback form, adaptive backstepping technique is a powerful tool. However, computation complexity caused by analytic computation of the higher derivatives of virtual control signals must be faced. Hence, how to reduce the computation becomes crucial issue in controller design.

2. **Motivation from practical application**

Decision threshold and algorithm. In some existing works, the asymptotic value of the state estimation error between the system state x and fault detection observer state $\hat{x}$, i.e., $\lim_{t\to\infty}(x(t) - \hat{x}(t)) = \lim_{t\to\infty} e_x(t) = e_x(\infty)$, is considered as an fault occurrence indicator. However, $e_x(\infty)$ is not available in practice, and $e_x(\infty) \neq 0$ cannot practically be considered as fault indicator. Hence, designing a more practical and efficient decision threshold and algorithm becomes more important and urgent.

Multi-type multi-fault isolation. In practical applications, multiple faults maybe simultaneously occur in the controlled systems. However, most of the results on FD in literature works under the restrictive condition that only one actuator or sensor fault occurs at one time, cannot be extended to the case where multiple actuator and sensor faults simultaneously occur. Therefore, it is a need for such case to design a novel FD observer to isolate multiple-type multiple faults occurred simultaneously.

Fault detection for time-delay systems. Most of fault detection observers of time-delay systems in literature contain time delay. If the time delay is unknown, then the observers are not reasonable and do not work in the practical applications. Hence, how to avoid the above shortcoming and design a proper observer for dynamical systems becomes important and practically useful.

Time delay due to fault diagnosis. There is always some level of time to detect, isolate and estimate the faults occurred in the systems. The time interval is called as the time delay due to fault diagnosis in this book. When faults occur, the faulty system works under the nominal control until the faults are diagnosed and fault accommodation is performed, which may cause severe loss of performance and stability. Hence, in the practical applications, the time delay due to FD should be derived strictly, and its adverse effect on the system performance should also be analyzed, and a proper solution is given to minimize its adverse effect.

This book provides recent theoretical results and applications of fault diagnosis and FTC for dynamic systems, including uncertain or certain systems, linear or nonlinear systems. Combining adaptive control technique with the other control technique or approaches, this book investigates the problem of FD and FTC for uncertain dynamic systems including linear and nonlinear systems with or without time delay.

This book intends to provide the readers a good understanding of FD and FTC based on adaptive control technology. The book can be used as a reference for the academic research on FD and FTC or used in Ph.D. study of control theory and engineering. The knowledge background for this monograph would be some undergraduate and graduate courses on linear system theory, nonlinear system theory, and FD and FTC control technology and theory.

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November 2015

http://www.springer.com/978-3-319-52529-7

Fault Diagnosis and Fault-Tolerant Control Based on
Adaptive Control Approach

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2017, XVIII, 239 p. 60 illus., 57 illus. in color., Hardcover
ISBN: 978-3-319-52529-7