



SUPERVISION, FAULT-DETECTION AND FAULT-DIAGNOSIS METHODS - AN INTRODUCTION

R. Isermann

Institute of Automatic Control, Laboratory of Control Engineering and Process Automation, Darmstadt University of Technology, Landgraf-Georg-Str. 4, D-64289 Darmstadt, Germany (Isermann@inf.fz.rwth-aachen.de, isermann@inf.fz.rwth-aachen.de)

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Abstract: The operation of technical processes requires increasingly advanced supervision and fault diagnosis to improve reliability, safety and economy. This paper gives an introduction to the field of fault detection and diagnosis. It begins with a consideration of a knowledge-based procedure that is based on analytical and heuristic information. Then different methods of fault detection are considered, which extract features from measured signals and use process and signal models. These methods are based on parameter estimation, state estimation and parity equations. By comparison with the normal behaviour, analytic symptoms are generated. Human operators are another source of information, and support the generation of heuristic symptoms. For fault diagnosis, all symptoms have to be processed in order to determine possible faults. This can be performed by classification methods or approximate reasoning, using probabilistic or possibilistic (fuzzy) approaches based on if-then-rules.

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Keywords: Fault detection, supervision, monitoring, parameter estimation, state estimation, parity equations, technical processes, actuators, sensors, fault diagnosis, diagnostic reasoning, fuzzy reasoning.

1. INTRODUCTION

Within the automatic control of technical systems, supervisory functions serve to indicate undesired or unpermitted process states, and to take appropriate actions in order to maintain the operation and to avoid damage or accidents. The following functions can be distinguished:

- (a) *monitoring:* measurable variables are checked with regard to tolerances, and alarms are generated for the operator.
- (b) *automatic protection:* in the case of a dangerous process state, the monitoring function automatically initiates an appropriate counteraction.
- (c) *supervision with fault diagnosis:* based on measured variables, features are calculated, symptoms are generated via change detection, a fault diagnosis is performed and decisions for counteractions are made.

The classical methods (a) and (b) are suitable for the overall supervision of the processes. To set the tolerances, compromises have to be made between the detection size of abnormal deviations and unnecessary alarms because of normal fluctuations of the variables. Most frequently, simple limit value checking is applied, which works especially well if the process operates approximately in a steady state. However, the situation becomes more involved if the process operating point changes rapidly. In the case of closed loops, changes in the process are covered by control actions and cannot be detected from the output signals, as long as the manipulated process inputs remain in the normal range. Therefore, feedback systems hinder the early detection of process faults.

The big advantage of the classical limit-value-based supervision methods is their simplicity and reliability. However, they are only able to react after a relatively large change of a feature, i.e. after either a large sudden fault or a long-lasting gradually increasing fault.

Supervision Fault Diagnosis And Fault Tolerance An Introduction

Elias Kyriakides, Marios Polycarpou



Supervision Fault Diagnosis And Fault Tolerance An Introduction:

Fault Detection, Supervision and Safety of Technical Processes 2003 (SAFEPROCESS 2003) Marcel Staroswiecki, Eva Wu, 2004-02-27 A three volume work bringing together papers presented at SAFEPROCESS 2003 including four plenary papers on statistical physical model based and logical model based approaches to fault detection and diagnosis as well as 178 regular papers

Fault-Diagnosis Systems Rolf Isermann, 2006-01-16 With increasing demands for efficiency and product quality plus progress in the integration of automatic control systems in high cost mechatronic and safety critical processes the field of supervision or monitoring fault detection and fault diagnosis plays an important role The book gives an introduction into advanced methods of fault detection and diagnosis FDD After definitions of important terms it considers the reliability availability safety and systems integrity of technical processes Then fault detection methods for single signals without models such as limit and trend checking and with harmonic and stochastic models such as Fourier analysis correlation and wavelets are treated This is followed by fault detection with process models using the relationships between signals such as parameter estimation parity equations observers and principal component analysis The treated fault diagnosis methods include classification methods from Bayes classification to neural networks with decision trees and inference methods from approximate reasoning with fuzzy logic to hybrid fuzzy neuro systems Several practical examples for fault detection and diagnosis of DC motor drives a centrifugal pump automotive suspension and tire demonstrate applications

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Diagnosis and Fault-tolerant Control Volume 2 Vicenc Puig, Silvio Simani, 2021-11-30 This book presents recent advances in fault diagnosis and fault tolerant control of dynamic processes Its impetus derives from the need for an overview of the challenges of the fault diagnosis technique and sustainable control especially for those demanding systems that require reliability availability maintainability and safety to ensure efficient operations Moreover the need for a high degree of tolerance with respect to

possible faults represents a further key point primarily for complex systems as modeling and control are inherently challenging and maintenance is both expensive and safety critical Diagnosis and Fault tolerant Control 2 also presents and compares different fault diagnosis and fault tolerant schemes using well established innovative strategies for modeling the behavior of the dynamic process under investigation An updated treatise of diagnosis and fault tolerant control is addressed with the use of essential and advanced methods including signal based model based and data driven techniques Another key feature is the application of these methods for dealing with robustness and reliability

Diagnosis and Fault-tolerant Control 1 Vicenc Puig, Silvio Simani, 2021-12-29 This book presents recent advances in fault diagnosis strategies for complex dynamic systems Its impetus derives from the need for an overview of the challenges of the fault diagnosis technique especially for those demanding systems that require reliability availability maintainability and safety to ensure efficient operations Moreover the need for a high degree of tolerance with respect to possible faults represents a further key point primarily for complex systems as modeling and control are inherently challenging and maintenance is both expensive and safety critical Diagnosis and Fault tolerant Control 1 also presents and compares different diagnosis schemes using established case studies that are widely used in related literature The main features of this book regard the analysis design and implementation of proper solutions for the problems of fault diagnosis in safety critical systems The design of the considered solutions involves robust data driven model based approaches

Fault-Diagnosis Applications Rolf Isermann, 2011-04-06 Supervision condition monitoring fault detection fault diagnosis and fault management play an increasing role for technical processes and vehicles in order to improve reliability availability maintenance and lifetime For safety related processes fault tolerant systems with redundancy are required in order to reach comprehensive system integrity This book is a sequel of the book Fault Diagnosis Systems published in 2006 where the basic methods were described After a short introduction into fault detection and fault diagnosis methods the book shows how these methods can be applied for a selection of 20 real technical components and processes as examples such as Electrical drives DC AC Electrical actuators Fluidic actuators hydraulic pneumatic Centrifugal and reciprocating pumps Pipelines leak detection Industrial robots Machine tools main and feed drive drilling milling grinding Heat exchangers Also realized fault tolerant systems for electrical drives actuators and sensors are presented The book describes why and how the various signal model based and process model based methods were applied and which experimental results could be achieved In several cases a combination of different methods was most successful The book is dedicated to graduate students of electrical mechanical chemical engineering and computer science and for engineers

Combustion Engine Diagnosis Rolf Isermann, 2017-05-04 This book offers first a short introduction to advanced supervision fault detection and diagnosis methods It then describes model based methods of fault detection and diagnosis for the main components of gasoline and diesel engines such as the intake system fuel supply fuel injection combustion process turbocharger exhaust system and

exhaust gas aftertreatment Additionally model based fault diagnosis of electrical motors electric pneumatic and hydraulic actuators and fault tolerant systems is treated In general series production sensors are used It includes abundant experimental results showing the detection and diagnosis quality of implemented faults Written for automotive engineers in practice it is also of interest to graduate students of mechanical and electrical engineering and computer science

Fault Diagnosis and Sustainable Control of Wind Turbines Silvio Simani,Saverio Farsoni,2018-01-02 Fault Diagnosis and Sustainable Control of Wind Turbines Robust Data Driven and Model Based Strategies discusses the development of reliable and robust fault diagnosis and fault tolerant sustainable control schemes by means of data driven and model based approaches These strategies are able to cope with unknown nonlinear systems and noisy measurements The book also discusses simpler solutions relying on data driven and model based methodologies which are key when on line implementations are considered for the proposed schemes The book targets both professional engineers working in industry and researchers in academic and scientific institutions In order to improve the safety reliability and efficiency of wind turbine systems thus avoiding expensive unplanned maintenance the accommodation of faults in their early occurrence is fundamental To highlight the potential of the proposed methods in real applications hardware in the loop test facilities representing realistic wind turbine systems are considered to analyze the digital implementation of the designed solutions The achieved results show that the developed schemes are able to maintain the desired performances thus validating their reliability and viability in real time implementations Different groups of readers ranging from industrial engineers wishing to gain insight into the applications potential of new fault diagnosis and sustainable control methods to the academic control community looking for new problems to tackle will find much to learn from this work Provides wind turbine models with varying complexity as well as the solutions proposed and developed by the authors Addresses in detail the design development and realistic implementation of fault diagnosis and fault tolerant control strategies for wind turbine systems Addresses the development of sustainable control solutions that in general do not require the introduction of further or redundant measurements Proposes active fault tolerant sustainable solutions that are able to maintain the wind turbine working conditions with gracefully degraded performance before required maintenance can occur Presents full coverage of the diagnosis and fault tolerant control problem starting from the modeling and identification and finishing with diagnosis and fault tolerant control approaches Provides MATLAB and Simulink codes for the solutions proposed

Diagnosis and Fault-Tolerant Control Mogens Blanke,Michel Kinnaert,Jan Lunze,Marcel Staroswiecki,2015-08-11 Fault tolerant control aims at a gradual shutdown response in automated systems when faults occur It satisfies the industrial demand for enhanced availability and safety in contrast to traditional reactions to faults which bring about sudden shutdowns and loss of availability The book presents effective model based analysis and design methods for fault diagnosis and fault tolerant control Architectural and structural models are used to analyse the propagation of the fault through the process to test the

fault detectability and to find the redundancies in the process that can be used to ensure fault tolerance It also introduces design methods suitable for diagnostic systems and fault tolerant controllers for continuous processes that are described by analytical models of discrete event systems represented by automata The book is suitable for engineering students engineers in industry and researchers who wish to get an overview of the variety of approaches to process diagnosis and fault tolerant control The authors have extensive teaching experience with graduate and PhD students as well as with industrial experts Parts of this book have been used in courses for this audience The authors give a comprehensive introduction to the main ideas of diagnosis and fault tolerant control and present some of their most recent research achievements obtained together with their research groups in a close cooperation with European research projects The third edition resulted from a major restructuring and re writing of the former edition which has been used for a decade by numerous research groups New material includes distributed diagnosis of continuous and discrete event systems methods for reconfigurability analysis and extensions of the structural methods towards fault tolerant control The bibliographical notes at the end of all chapters have been up dated The chapters end with exercises to be used in lectures

Integrated Uncertainty in Knowledge Modelling and Decision Making Van-Nam Huynh,Masahiro Inuiguchi,Bac Le,Bao Nguyen Le,Thierry Denoeux,2016-11-21 This book constitutes the refereed proceedings of the 5th International Symposium on Integrated Uncertainty in Knowledge Modelling and Decision Making IUKM 2016 held in Da Nang Vietnam in November December 2016 The IUKM symposia aim to provide a forum for exchanges of research results and ideas and experience of application among researchers and practitioners involved with all aspects of uncertainty modelling and management

Monitoring and Control of Information-Poor Systems Arthur L. Dexter,2012-02-16 The monitoring and control of a system whose behaviour is highly uncertain is an important and challenging practical problem Methods of solution based on fuzzy techniques have generated considerable interest but very little of the existing literature considers explicit ways of taking uncertainties into account This book describes an approach to the monitoring and control of information poor systems that is based on fuzzy relational models which generate fuzzy outputs The first part of Monitoring and Control of Information Poor Systems aims to clarify why design decisions must take account of the uncertainty associated with optimal choices and to explain how a fuzzy relational model can be used to generate a fuzzy output which reflects the uncertainties associated with its predictions Part two gives a brief introduction to fuzzy decision making and shows how it can be used to design a predictive control scheme that is suitable for controlling information poor systems using inaccurate measurements Part three describes different ways in which fuzzy relational models can be generated online and explains the practical issues associated with their identification and application The final part of the book provides examples of the use of the previously described techniques in real applications Key features Describes techniques applicable to a wide range of engineering environmental medical financial and economic applications Uses simple examples to help explain the basic techniques for dealing with uncertainty Describes a novel design

approach based on the use of fuzzy relational models Considers practical issues associated with applying the techniques to real systems Monitoring and Control of Information Poor Systems forms an invaluable resource for a wide range of graduate students and is also a comprehensive reference for researchers and practitioners working on problems involving mathematical modelling and control

Fault-tolerant Control Systems Hassan Noura,Didier Theilliol,Jean-Christophe Ponsart,Abbas Chamseddine,2009-07-30 The seriesAdvancesinIndustrialControl aims to report and encourage technologytransfer in controlengineering The rapid development of control technology has an impact on all areas of the control discipline New theory new controllers actuators sensors new industrial processes computer methods new applications new philosophies new challenges Much of this development work resides in industrial reports feasibility study papers and the ports of advanced collaborative projects The series offers an opportunity for researchers to present an extended exposition of such new work in all aspects of industrial control for wider and rapid dissemination Control system design and technology continues to develop in many different directions One theme that the Advances in Industrial Control series is following is the application of nonlinear control design methods and the series has some interesting new commissions in progress However another theme of interest is how to endow the industrial controller with the ability to overcome faults and process degradation Fault detection and isolation is a broad field with a research literature spanning several decades This topic deals with three questions How is the presence of a fault detected What is the cause of the fault Where is it located However there has been less focus on the question of how to use the control system to accommodate and overcome the performance deterioration caused by the identified sensor or actuator fault

Advanced Solutions in Diagnostics and Fault Tolerant Control Jan M. Kościelny,Michał Syfert,Anna Szttyber,2017-07-28 This book highlights the latest achievements concerning the theory methods and practice of fault diagnostics fault tolerant systems and cyber safety When considering the diagnostics of industrial processes and systems increasingly important safety issues cannot be ignored In this context diagnostics plays a crucial role as a primary measure of the improvement of the overall system safety integrity level Obtaining the desired diagnostic coverage or providing an appropriate level of inviolability of the integrity of a system is now practically inconceivable without the use of fault detection and isolation methods Given the breadth and depth of its coverage the book will be of interest to researchers faced with the challenge of designing technical and medical diagnosis systems as well as junior researchers and students in the fields of automatic control robotics computer science and artificial intelligence

Intelligent Monitoring, Control, and Security of Critical Infrastructure Systems Elias Kyriakides,Marios Polycarpou,2014-09-13 This book describes the challenges that critical infrastructure systems face and presents state of the art solutions to address them How can we design intelligent systems or intelligent agents that can make appropriate real time decisions in the management of such large scale complex systems What are the primary challenges for critical infrastructure systems The book also provides readers with the relevant information to recognize how important

infrastructures are and their role in connection with a society's economy security and prosperity. It goes on to describe state of the art solutions to address these points including new methodologies and instrumentation tools e.g. embedded software and intelligent algorithms for transforming and optimizing target infrastructures. The book is the most comprehensive resource to date for professionals in both the private and public sectors while also offering an essential guide for students and researchers in the areas of modeling and analysis of critical infrastructure systems monitoring control risk impact evaluation fault diagnosis fault tolerant control and infrastructure dependencies interdependencies. The importance of the research presented in the book is reflected in the fact that currently for the first time in human history more people live in cities than in rural areas and that by 2050 roughly 70% of the world's total population is expected to live in cities. **Fault**

Detection, Supervision and Safety of Technical Processes 2006 Hong-Yue Zhang, 2007-03-01 The safe and reliable operation of technical systems is of great significance for the protection of human life and health the environment and of the vested economic value. The correct functioning of those systems has a profound impact also on production cost and product quality. The early detection of faults is critical in avoiding performance degradation and damage to the machinery or human life. Accurate diagnosis then helps to make the right decisions on emergency actions and repairs. Fault detection and diagnosis FDD has developed into a major area of research at the intersection of systems and control engineering artificial intelligence applied mathematics and statistics and such application fields as chemical electrical mechanical and aerospace engineering. IFAC has recognized the significance of FDD by launching a triennial symposium series dedicated to the subject. The SAFEPROCESS Symposium is organized every three years since the first symposium held in Baden Baden in 1991. SAFEPROCESS 2006 the 6th IFAC Symposium on Fault Detection Supervision and Safety of Technical Processes was held in Beijing PR China. The program included three plenary papers two semi plenary papers two industrial talks by internationally recognized experts and 258 regular papers which have been selected out of a total of 387 regular and invited papers submitted. Discusses the developments and future challenges in all aspects of fault diagnosis and fault tolerant control 8 invited and 36 contributed sessions included with a special session on the demonstration of process monitoring and diagnostic software tools. **Robust Integration of Model-Based Fault Estimation and Fault-Tolerant Control**

Jianglin Lan, Ronald J. Patton, 2020-12-11 Robust Integration of Model Based Fault Estimation and Fault Tolerant Control is a systematic examination of methods used to overcome the inevitable system uncertainties arising when a fault estimation FE function and a fault tolerant controller interact as they are employed together to compensate for system faults and maintain robustly acceptable system performance. It covers the important subject of robust integration of FE and FTC with the aim of guaranteeing closed loop stability. The reader's understanding of the theory is supported by the extensive use of tutorial examples including some MATLAB based material available from the Springer website and by industrial applications based material. The text is structured into three parts. Part I examines the basic concepts of FE and FTC providing extensive insight

into the importance of and challenges involved in their integration Part II describes five effective strategies for the integration of FE and FTC sequential iterative simultaneous adaptive decoupling and robust decoupling and Part III begins to extend the proposed strategies to nonlinear and large scale systems and covers their application in the fields of renewable energy robotics and networked systems The strategies presented are applicable to a broad range of control problems because in the absence of faults the FE based FTC naturally reverts to conventional observer based control The book is a useful resource for researchers and engineers working in the area of fault tolerant control systems and supplementary material for a graduate or postgraduate level course on fault diagnosis and FTC Advances in Industrial Control reports and encourages the transfer of technology in control engineering The rapid development of control technology has an impact on all areas of the control discipline The series offers an opportunity for researchers to present an extended exposition of new work in all aspects of industrial control

Fault Diagnosis and Fault-Tolerant Control Strategies for Non-Linear Systems Marcin Witczak, 2013-12-11 This book presents selected fault diagnosis and fault tolerant control strategies for non linear systems in a unified framework In particular starting from advanced state estimation strategies up to modern soft computing the discrete time description of the system is employed Part I of the book presents original research results regarding state estimation and neural networks for robust fault diagnosis Part II is devoted to the presentation of integrated fault diagnosis and fault tolerant systems It starts with a general fault tolerant control framework which is then extended by introducing robustness with respect to various uncertainties Finally it is shown how to implement the proposed framework for fuzzy systems described by the well known Takagi Sugeno models This research monograph is intended for researchers engineers and advanced postgraduate students in control and electrical engineering computer science as well as mechanical and chemical engineering

Modelling and Estimation Strategies for Fault Diagnosis of Non-Linear Systems Marcin Witczak, 2007-07-08 This monograph presents a variety of techniques that can be used for designing robust fault diagnosis schemes for non linear systems The introductory part of the book is of a tutorial value and can be perceived as a good starting point for the new comers to this field Subsequently advanced robust observer structures are presented Parameter estimation based techniques are discussed as well A particular attention is drawn to experimental design for fault diagnosis The book also presents a number of robust soft computing approaches utilizing evolutionary algorithms and neural networks All approaches described in this book are illustrated by practical applications

Analysis and Synthesis of Fault-Tolerant Control Systems Magdi S. Mahmoud, Yuanqing Xia, 2013-10-28 In recent years control systems have become more sophisticated in order to meet increased performance and safety requirements for modern technological systems Engineers are becoming more aware that conventional feedback control design for a complex system may result in unsatisfactory performance or even instability in the event of malfunctions in actuators sensors or other system components In order to circumvent such weaknesses new approaches to control system design have emerged which can tolerate

component malfunctions while maintaining acceptable stability and performance These types of control systems are often known as fault tolerant control systems FTCS More precisely FTCS are control systems which possess the ability to accommodate component failure automatically Analysis and Synthesis of Fault Tolerant Control Systems comprehensively covers the analysis and synthesis methods of fault tolerant control systems It unifies the methods for developing controllers and filters for a wide class of dynamical systems and reports on the recent technical advances in design methodologies MATLAB is used throughout the book to demonstrate methods of analysis and design Key features Provides advanced theoretical methods and typical practical applications Provides access to a spectrum of control design methods applied to industrial systems Includes case studies and illustrative examples Contains end of chapter problems Analysis and Synthesis of Fault Tolerant Control Systems is a comprehensive reference for researchers and practitioners working in this area and is also a valuable source of information for graduates and senior undergraduates in control mechanical aerospace electrical and mechatronics engineering departments Reconfigurable Control of Nonlinear Dynamical Systems Jan H.

Richter,2011-01-16 This research monograph summarizes solutions to reconfigurable fault tolerant control problems for nonlinear dynamical systems that are based on the fault hiding principle It emphasizes but is not limited to complete actuator and sensor failures In the first part the monograph starts with a broad introduction of the control reconfiguration problems and objectives as well as summaries and explanations of solutions for linear dynamical systems The solution is always a reconfiguration block which consists of linear virtual actuators in the case of actuator faults and linear virtual sensors in the case of sensor faults The main advantage of the fault hiding concept is the reusability of the nominal controller which remains in the loop as an active system while the virtual actuator and sensor adapt the control input and the measured output to the fault scenario The second and third parts extend virtual actuators and virtual sensors towards the classes of Hammerstein Wiener systems and piecewise affine systems The main analyses concern stability recovery setpoint tracking recovery and performance recovery as reconfiguration objectives The fourth part concludes the monograph with descriptions of practical implementations and case studies The book is primarily intended for active researchers and practicing engineers in the field of fault tolerant control Due to many running examples it is also suitable for interested graduate students

The book delves into Supervision Fault Diagnosis And Fault Tolerance An Introduction. Supervision Fault Diagnosis And Fault Tolerance An Introduction is an essential topic that must be grasped by everyone, ranging from students and scholars to the general public. This book will furnish comprehensive and in-depth insights into Supervision Fault Diagnosis And Fault Tolerance An Introduction, encompassing both the fundamentals and more intricate discussions.

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