Data Driven Methods For Fault Detection And Diagnosis In Chemical Processes
Advances In Industrial Control

In many industrial applications early detection and diagnosis of abnormal behavior of the plant is of great importance. During the last decades, the complexity of process plants has been drastically increased, which imposes great challenges in development of model-based monitoring approaches and it sometimes becomes unrealistic for modern large-scale processes. The main objective of Adel Haghani Abandan Sari is to study efficient fault diagnosis techniques for complex industrial systems using process historical data and considering the nonlinear behavior of the process. To this end, different methods are presented to solve the fault diagnosis problem based on the overall behavior of the process and its dynamics. Moreover, a novel technique is proposed for fault isolation and determination of the root-cause of the faults in the system, based on the fault impacts on the process measurements.

Fault diagnosis is useful for technicians to detect, isolate, identify faults, and troubleshoot. Bayesian network (BN) is a probabilistic graphical model that effectively deals with various uncertainty problems. This model is increasingly utilized in fault diagnosis. This unique compendium presents bibliographical review on the use of BNs in fault diagnosis in the last decades with focus on engineering systems. Subsequently, eleven important issues in BN-based fault diagnosis methodology, such as BN structure modeling, BN parameter modeling, BN inference, fault identification, validation, and verification are discussed in various cases. Researchers, professionals, academics and graduate students will better understand the theory and application, and benefit those who are keen to develop real BN-based fault diagnosis system.

This book assesses the potential of data-driven methods in industrial process monitoring engineering. The process modeling, fault detection, classification, isolation, and reasoning are studied in detail. These methods can be used to improve the safety and reliability of industrial processes. Fault diagnosis, including fault detection and reasoning, has attracted engineers and scientists from various fields such as control, machinery, mathematics, and automation engineering. Combining the diagnosis algorithms and application cases, this book establishes a basic framework for this topic and implements various statistical analysis methods for process monitoring. This book is intended for senior undergraduate and graduate students who are interested in fault diagnosis technology, researchers investigating automation and industrial security, professional practitioners and engineers working on engineering modeling and data processing applications.

Modern industrial processes are becoming more complex, and consequently monitoring them has become a challenging task. Fault Detection and Diagnosis (F01) as a key element of process monitoring, needs to be investigated because of its essential role in decision making processes. Among available F01 methods, data driven approaches are currently receiving increasing attention because of their relative simplicity in implementation. Regardless of F01 types, one of the main traits of reliable F01 systems is their ability of being updated while new conditions that were not considered at their initial training appear in the process. These
new conditions would emerge either gradually or abruptly, but they have the same level of importance as in both cases they lead to F01 poor performance. For addressing updating tasks, some methods have been proposed, but mainly not in research area of chemical engineering. They could be categorized to those that are dedicated to managing Concept Drift (CD) (that appear gradually), and those that deal with novel classes (that appear abruptly). The available methods, mainly, in addition to the lack of clear strategies for updating, suffer from performance weaknesses and inefficient required time of training, as reported. Accordingly, this thesis is mainly dedicated to data driven F01 updating in chemical processes. The proposed schemes for handling novel classes of faults are based on unsupervised methods, while for coping with CD both supervised and unsupervised updating frameworks have been investigated. Furthermore, for enhancing the functionality of F01 systems, some major methods of data processing, including imputation of missing values, feature selection, and feature extension have been investigated. The suggested algorithms and frameworks for F01 updating have been evaluated through different benchmarks and scenarios. As a part of the results, the suggested algorithms for supervised handling CD surpass the performance of the traditional incremental learning in regard to MGM score (defined dimensionless score based on weighted F1 score and training time) even up to 50% improvement. This improvement is achieved by proposed algorithms that detect and forget redundant information as well as properly adjusting the data window for timely updating and retraining the fault detection system. Moreover, the proposed unsupervised F01 updating framework for dealing with novel faults in static and dynamic process conditions achieves up to 90% in terms of the NPP score (defined dimensionless score based on number of the correct predicted class of samples). This result relies on an innovative framework that is able to assign samples either to new classes or to available classes by exploiting one class classification techniques and clustering approaches.

This book is a comprehensive collection of chapters focusing on the core areas of computing and their further applications in the real world. Each chapter is a paper presented at the Computing Conference 2021 held on 15-16 July 2021. Computing 2021 attracted a total of 638 submissions which underwent a double-blind peer review process. Of those 638 submissions, 235 submissions have been selected to be included in this book. The goal of this conference is to give a platform to researchers with fundamental contributions and to be a premier venue for academic and industry practitioners to share new ideas and development experiences. We hope that readers find this volume interesting and valuable as it provides the state-of-the-art intelligent methods and techniques for solving real-world problems. We also expect that the conference and its publications is a trigger for further related research and technology improvements in this important subject.

This utterly comprehensive work is thought to be the first to integrate the literature on the physics of the failure of complex systems such as hospitals, banks and transport networks. It has chapters on particular aspects of maintenance written by internationally-renowned researchers and practitioners. This book will interest maintenance engineers and managers in industry as well as researchers and graduate students in maintenance, industrial engineering and applied mathematics.

Fault Diagnosis of Dynamic Systems provides readers with a glimpse into the fundamental issues and techniques of fault
diagnosis used by Automatic Control (FDI) and Artificial Intelligence (DX) research communities. The book reviews the standard techniques and approaches widely used in both communities. It also contains benchmark examples and case studies that demonstrate how the same problem can be solved using the presented approaches. The book also introduces advanced fault diagnosis approaches that are currently still being researched, including methods for non-linear, hybrid, discrete-event and software/business systems, as well as, an introduction to prognosis. Fault Diagnosis of Dynamic Systems is valuable source of information for researchers and engineers starting to work on fault diagnosis and willing to have a reference guide on the main concepts and standard approaches on fault diagnosis. Readers with experience on one of the two main communities will also find it useful to learn the fundamental concepts of the other community and the synergies between them. The book is also open to researchers or academics who are already familiar with the standard approaches, since they will find a collection of advanced approaches with more specific and advanced topics or with application to different domains. Finally, engineers and researchers looking for transferable fault diagnosis methods will also find useful insights in the book.

This book gathers the proceedings of the 1st International Conference on Engineering, Applied Sciences and System Modeling (ICEASSM), a four-day event (18th–21st April 2017) held in Accra, Ghana. It focuses on research work promoting a better understanding of engineering problems through applied sciences and modeling, and on solutions generated in an African setting but with relevance to the world as a whole. The book provides a holistic overview of challenges facing Africa, and addresses various areas from research and development perspectives. Presenting contributions by scientists, engineers and experts hailing from a host of international institutions, the book offers original approaches and technological solutions to help solve real-world problems through research and knowledge sharing. Further, it explores promising opportunities for collaborative research on issues of scientific, economic and social development, making it of interest to researchers, scientists and practitioners looking to conduct research in disciplines such as water supply, control, civil engineering, statistical modeling, renewable energy and sustainable urban development.

Control systems at production plants consist of a large number of process variables. When detecting abnormal behavior, these variables generate an alarm. Due to the interconnection of the plant's devices the fault can lead to an alarm flood. This again hides the original location of the causing device. In this work several data-driven approaches for root cause localization are proposed, compared and combined. All methods analyze disturbed process data for backtracking the propagation path. This work was published by Saint Philip Street Press pursuant to a Creative Commons license permitting commercial use. All rights not granted by the work's license are retained by the author or authors.
Data-Driven and Model-Based Methods for Fault Detection and Diagnosis covers techniques that improve the quality of fault detection and enhance monitoring through chemical and environmental processes. The book provides both the theoretical framework and technical solutions. It starts with a review of relevant literature, proceeds with a detailed description of developed methodologies, and then discusses the results of developed methodologies, and ends with major conclusions reached from the analysis of simulation and experimental studies. The book is an indispensable resource for researchers in academia and industry and practitioners working in chemical and environmental engineering to do their work safely. Outlines latent variable based hypothesis testing fault detection techniques to enhance monitoring processes represented by linear or nonlinear input-space models (such as PCA) or input-output models (such as PLS). Explains multiscale latent variable based hypothesis testing fault detection techniques using multiscale representation to help deal with uncertainty in the data and minimize its effect on fault detection. Includes interval PCA (IPCA) and interval PLS (IPLS) fault detection methods to enhance the quality of fault detection. Provides model-based detection techniques for the improvement of monitoring processes using state estimation-based fault detection approaches. Demonstrates the effectiveness of the proposed strategies by conducting simulation and experimental studies on synthetic data.

This book addresses the needs of researchers and practitioners in the field of high-speed trains, especially those whose work involves safety and reliability issues in traction systems. It will appeal to researchers and graduate students at institutions of higher learning, research labs, and in the industrial R&D sector, catering to a readership from a broad range of disciplines including intelligent transportation, electrical engineering, mechanical engineering, chemical engineering, the biological sciences and engineering, economics, ecology, and the mathematical sciences.

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.

Reliability Analysis and Asset Management of Engineering Systems explains methods that can be used to evaluate reliability and availability of complex systems, including simulation-based methods. The increasing digitization of mechanical processes driven by Industry 4.0
increases the interaction between machines and monitoring and control systems, leading to increases in system complexity. For those systems the reliability and availability analyses are increasingly challenging, as the interaction between machines has become more complex, and the analysis of the flexibility of the production systems to respond to machinery failure may require advanced simulation techniques. This book fills a gap on how to deal with such complex systems by linking the concepts of systems reliability and asset management, and then making these solutions more accessible to industry by explaining the availability analysis of complex systems based on simulation methods that emphasise Petri nets. Explains how to use a monitoring database to perform important tasks including an update of complex systems reliability Shows how to diagnose probable machinery-based causes of system performance degradation by using a monitoring database and reliability estimates in an integrated way Describes practical techniques for the application of AI and machine learning methods to fault detection and diagnosis problems.

Applications of Artificial Intelligence in Process Systems Engineering offers a broad perspective on the issues related to artificial intelligence technologies and their applications in chemical and process engineering. The book comprehensively introduces the methodology and applications of AI technologies in process systems engineering, making it an indispensable reference for researchers and students. As chemical processes and systems are usually non-linear and complex, thus making it challenging to apply AI methods and technologies, this book is an ideal resource on emerging areas such as cloud computing, big data, the industrial Internet of Things and deep learning. With process systems engineering's potential to become one of the driving forces for the development of AI technologies, this book covers all the right bases. Explains the concept of machine learning, deep learning and state-of-the-art intelligent algorithms Discusses AI-based applications in process modeling and simulation, process integration and optimization, process control, and fault detection and diagnosis Gives direction to future development trends of AI technologies in chemical and process engineering.

In the current age of information explosion, newly invented technological sensors and software are now tightly integrated with our everyday lives. Many sensor processing algorithms have incorporated some forms of computational intelligence as part of their core framework in problem solving. These algorithms have the capacity to generalize and discover knowledge for themselves and learn new information whenever unseen data are captured. The primary aim of sensor processing is to develop techniques to interpret, understand, and act on information contained in the data. The interest of this book is in developing intelligent signal processing in order to pave the way for smart sensors. This involves mathematical advancement of nonlinear signal processing theory and its applications that extend far beyond traditional techniques. It bridges the boundary between theory and application, developing novel theoretically inspired methodologies targeting both longstanding and emergent signal processing applications. The topic ranges from phishing detection to integration of terrestrial laser scanning, and from fault diagnosis to bio-inspiring filtering. The book will appeal to established practitioners, along with researchers and students in the emerging field of smart sensors processing.

This book constitutes selected papers from the Second International Workshop on IoT Streams for Data-Driven Predictive Maintenance, IoT Streams 2020, and First International Workshop on IoT, Edge, and Mobile for Embedded Machine Learning, ITEM 2020, co-located with ECML/PKDD 2020 and held in September 2020. Due to the COVID-19 pandemic the workshops were held online. The 21 full papers and 3 short papers presented in this volume were thoroughly reviewed and selected from 35 submissions and are organized according to the workshops and their topics: IoT Streams 2020: Stream Learning; Feature Learning; ITEM 2020: Unsupervised Machine Learning; Hardware; Methods; Quantization.
The major objective of this book is to introduce advanced design and (online) optimization methods for fault diagnosis and fault-tolerant control from different aspects. Under the aspect of system types, fault diagnosis and fault-tolerant issues are dealt with for linear time-invariant and time-varying systems as well as for nonlinear and distributed (including networked) systems. From the methodological point of view, both model-based and data-driven schemes are investigated. To allow for a self-contained study and enable an easy implementation in real applications, the necessary knowledge as well as tools in mathematics and control theory are included in this book. The main results with the fault diagnosis and fault-tolerant schemes are presented in form of algorithms and demonstrated by means of benchmark case studies. The intended audience of this book are process and control engineers, engineering students and researchers with control engineering background.

This thesis develops a systematic, data-based dynamic modeling framework for industrial processes in keeping with the slowness principle. Using said framework as a point of departure, it then proposes novel strategies for dealing with control monitoring and quality prediction problems in industrial production contexts. The thesis reveals the slowly varying nature of industrial production processes under feedback control, and integrates it with process data analytics to offer powerful prior knowledge that gives rise to statistical methods tailored to industrial data. It addresses several issues of immediate interest in industrial practice, including process monitoring, control performance assessment and diagnosis, monitoring system design, and product quality prediction. In particular, it proposes a holistic and pragmatic design framework for industrial monitoring systems, which delivers effective elimination of false alarms, as well as intelligent self-running by fully utilizing the information underlying the data. One of the strengths of this thesis is its integration of insights from statistics, machine learning, control theory and engineering to provide a new scheme for industrial process modeling in the era of big data.

Data-driven Design of Fault Diagnosis and Fault-tolerant Control Systems

Early and accurate fault detection and diagnosis for modern chemical plants can minimize downtime, increase the safety of plant operations, and reduce manufacturing costs. The process-monitoring techniques that have been most effective in practice are based on models constructed almost entirely from process data. The goal of the book is to present the theoretical background and practical techniques for data-driven process monitoring. Process-monitoring techniques presented include: Principal component analysis; Fisher discriminant analysis; Partial least squares; Canonical variate analysis. The text demonstrates the application of all of the data-driven process monitoring techniques to the Tennessee Eastman plant simulator - demonstrating the strengths and weaknesses of each approach in detail. This aids the reader in selecting the right method for his process application. Plant simulator and homework problems in which students apply the process-monitoring techniques to a nontrivial simulated process, and can compare their performance with that obtained in the case studies in the text are included. A number of additional homework problems encourage the reader to implement and obtain a deeper understanding of the techniques. The reader will obtain a background in data-driven techniques for fault detection and diagnosis, including the ability to implement the techniques and to know how to select the right technique for a particular application.
The main objective of Data-Driven and Model-Based Methods for Fault Detection and Diagnosis is to develop techniques that improve the quality of fault detection and then utilize these developed techniques to enhance monitoring various chemical and environmental processes. The book provides both the theoretical framework and technical solutions. It starts with reviewing relevant literature, proceeds with a detailed description of developed methodologies, followed by a discussion of the results of developed methodologies, and ends with major conclusions reached from the analysis of simulation and experimental studies. The book is an indispensable resource for researchers in academia and industry and practitioners working in chemical and environmental engineering to do their work safely. Outlines latent variable based hypothesis testing fault detection techniques to enhance monitoring processes represented by linear or nonlinear input-space models (such as PCA) or input-output models (such as PLS) Explains multiscale latent variable based hypothesis testing fault detection techniques using multiscale representation to help deal with uncertainty in the data and minimize its effect on fault detection Includes interval PCA (IPCA) and interval PLS (IPLS) fault detection methods to enhance the quality of fault detection Provides model-based detection techniques for improvement of monitoring processes using state estimation-based fault detection approaches Demonstrates the effectiveness of the proposed strategies by conducting simulation and experimental studies on synthetic data Early and accurate fault detection and diagnosis for modern chemical plants can minimize downtime, increase the safety of plant operations, and reduce manufacturing costs. This book presents the theoretical background and practical techniques for data-driven process monitoring. It demonstrates the application of all the data-driven process monitoring techniques to the Tennessee Eastman plant simulator, and looks at the strengths and weaknesses of each approach in detail. A plant simulator and problems allow readers to apply process monitoring techniques.

Aiming at improving the reliability and durability of Polymer Electrolyte Membrane Fuel Cell (PEMFC) systems and promote the commercialization of fuel cell technologies, this thesis work is dedicated to the fault diagnosis study for PEMFC systems. Data-driven fault diagnosis is the main focus in this thesis. As a main branch of data-driven fault diagnosis, the methods based on pattern classification techniques are firstly studied. Taking individual fuel cell voltages as original diagnosis variables, several representative methodologies are investigated and compared from the perspective of online implementation. Specific to the defects of conventional classification based diagnosis methods, a novel diagnosis strategy is proposed. A new classifier named Sphere-Shaped Multi-class Support Vector Machine (SSM-SVM) and modified diagnostic rules are utilized to realize the novel fault recognition. While an incremental learning method is extended to achieve the online adaptation. Apart from the classification based diagnosis approach, a so-called partial model-based data-driven approach is introduced to handle PEMFC diagnosis in dynamic processes. With the aid
of a subspace identification method (SIM), the model-based residual generation is designed directly from the normal and
dynamic operating data. Then, fault detection and isolation are further realized by evaluating the generated residuals.
The proposed diagnosis strategies have been verified using the experimental data which cover a set of representative faults
and different PEMFC stacks. The preliminary online implementation results with an embedded system are also supplied.
This book examines recent methods for data-driven fault diagnosis of multimode continuous processes. It formalizes,
generalizes, and systematically presents the main concepts, and approaches required to design fault diagnosis methods
for multimode continuous processes. The book provides both theoretical and practical tools to help readers address the
fault diagnosis problem by drawing data-driven methods from at least three different areas: statistics, unsupervised, and
supervised learning.

This book provides a complete picture of several decision support tools for predictive maintenance. These include
embedding early anomaly/fault detection, diagnosis and reasoning, remaining useful life prediction (fault prognostics),
quality prediction and self-reaction, as well as optimization, control and self-healing techniques. It shows recent
applications of these techniques within various types of industrial (production/utilities/equipment/plants/smart devices,
etc.) systems addressing several challenges in Industry 4.0 and different tasks dealing with Big Data Streams, Internet of
Things, specific infrastructures and tools, high system dynamics and non-stationary environments. Applications
discussed include production and manufacturing systems, renewable energy production and management, maritime
systems, power plants and turbines, conditioning systems, compressor valves, induction motors, flight simulators, railway
infrastructures, mobile robots, cyber security and Internet of Things. The contributors go beyond state of the art by
placing a specific focus on dynamic systems, where it is of utmost importance to update system and maintenance models
on the fly to maintain their predictive power.

Zhiwen Chen aims to develop advanced fault detection (FD) methods for the monitoring of industrial processes. With the
ever increasing demands on reliability and safety in industrial processes, fault detection has become an important issue.
Although the model-based fault detection theory has been well studied in the past decades, its applications are limited to
large-scale industrial processes because it is difficult to build accurate models. Furthermore, motivated by the limitations
of existing data-driven FD methods, novel canonical correlation analysis (CCA) and projection-based methods are
proposed from the perspectives of process input and output data, less engineering effort and wide application scope. For
performance evaluation of FD methods, a new index is also developed.

Safety Theory and Technology of High-Speed Train Operation puts forward solutions for train dispatching and signal
control. Frequent railway incidents have threatened the safety of rail transport. In 2013, more than 12 trains collided. In
the same year, a Spanish train derailed due to speed, and two of China’s high-speed trains collided. In 2016, Germany and Italy both experienced serious train collisions. Global railway security is essential. Many accidents are caused by train dispatching errors and signal system failure. Chinese high-speed railway has developed very quickly and at a very large scale. However, many issues regarding safety has not been addressed. This book considers the issue from the perspective of a system. A train operation control system structure is put forward in order to ensure safety. Five key technologies (namely system-level fail-safe, parallel monitoring, completeness of train control data, data sharing and fusion and prevention of common errors in monitoring), are proposed. In order to prevent collision, over-speed, derailment, and rear-end collision accidents, the concept and corresponding parallel monitoring technology of five core control items (train route, speed, tracking interval, temporary speed limit, train running state) is proposed. Puts forward solutions for train dispatching and signal control. Views high-speed train safety and technology from a systems-theory perspective. Describes five key technologies to ensure safety. Proposes five parallel monitoring technologies to prevent collision, over-speed, derailment and rear-end collision incidents. Considers the very quick and large-scale development of Chinese high-speed rail.

Data-driven Design of Fault Diagnosis and Fault-tolerant Control Systems presents basic statistical process monitoring, fault diagnosis, and control methods and introduces advanced data-driven schemes for the design of fault diagnosis and fault-tolerant control systems catering to the needs of dynamic industrial processes. With ever increasing demands for reliability, availability and safety in technical processes and assets, process monitoring and fault-tolerance have become important issues surrounding the design of automatic control systems. This text shows the reader how, thanks to the rapid development of information technology, key techniques of data-driven and statistical process monitoring and control can now become widely used in industrial practice to address these issues. To allow for self-contained study and facilitate implementation in real applications, important mathematical and control theoretical knowledge and tools are included in this book. Major schemes are presented in algorithm form and demonstrated on industrial case systems. Data-driven Design of Fault Diagnosis and Fault-tolerant Control Systems will be of interest to process and control engineers, engineering students and researchers with a control engineering background.

This unique text/reference describes in detail the latest advances in unsupervised process monitoring and fault diagnosis with machine learning methods. Abundant case studies throughout the text demonstrate the efficacy of each method in real-world settings. The broad coverage examines such cutting-edge topics as the use of information theory to enhance unsupervised learning in tree-based methods, the extension of kernel methods to multiple kernel learning for feature extraction from data, and the incremental training of multilayer perceptrons to construct deep architectures for enhanced
data projections. Topics and features: discusses machine learning frameworks based on artificial neural networks, statistical learning theory and kernel-based methods, and tree-based methods; examines the application of machine learning to steady state and dynamic operations, with a focus on unsupervised learning; describes the use of spectral methods in process fault diagnosis.

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