
Plug-and-Play Monitoring and Performance Optimization for Industrial Automation Processes

Hao Luo

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 Springer Vieweg

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Duisburg, Deutschland

Von der Fakultät für Ingenieurwissenschaften, Abteilung Elektrotechnik und Informationstechnik der Universität Duisburg-Essen zur Erlangung des akademischen Grades Doktor der Ingenieurwissenschaften (Dr.-Ing.) genehmigte Dissertation von Hao Luo aus Yunnan, V.R. China.

1. Gutachter: Prof. Dr.-Ing. Steven X. Ding
2. Gutachter: Prof. Dr.-Ing. Shen Yin
3. Gutachter: Prof. Dr. Okyay Kaynak Datum der mündlichen Prüfung: 20. Juli 2016

ISBN 978-3-658-15927-6 ISBN 978-3-658-15928-3 (eBook)
DOI 10.1007/978-3-658-15928-3

Library of Congress Control Number: 2016954803

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Printed on acid-free paper

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The registered company is Springer Fachmedien Wiesbaden GmbH
The registered company address is: Abraham-Lincoln-Str. 46, 65189 Wiesbaden, Germany

Acknowledgements

This work was done during my Ph.D. study in the Institute for Automatic Control and Complex Systems (AKS) in the Faculty of Engineering at the University of Duisburg-Essen, Germany. I would like to give my deepest sincere thanks to Prof. Dr.-Ing. Steven X. Ding, my honorable mentor, who opened me the gate to the scientific world. I am grateful forever for his guidance and influence on my scientific research work. My sincere appreciation must also go to Prof. Dr.-Ing. Shen Yin and Prof. Dr. Okyay Kaynak for their interests in my work and being my reviewers. Their valuable comments expanded my horizon and improved the quality of this thesis.

I would like to express my heartfelt thanks to my group colleagues M.Sc. Minjia Chang, M.Sc. Tim Könings for the valuable discussions and their wholehearted help and supports, I cannot finish my work at this level without their help. Moreover, I would like to thank my former group colleagues, Dr.-Ing. Adel Haghani and Dr.-Ing. Haiyang Hao, for all the discussions and teamwork during the EC project. I would also like to thank Dr. Shasha Li, M.Sc. Judith Minten and Dr.-Ing. Chris Louen for the constructive discussions and cooperation during the BMBF project. Special thanks to Dr.-Ing. Birgit Köppen-Seliger for her rich experiences on research projects and valuable suggestions. I would also like to thank Dipl.-Ing. Eberhard Goldschmidt for his earnest advices and timely supports during my teaching activities.

I would like to thank my wonderful AKS colleagues who always offered me great help during my study. My thanks go to Dr.-Ing. Ying Wang, Dr.-Ing. Dongmei Xu, Dr.-Ing. Linlin Li, M.Sc. Sihan Yu, M.Sc. Kristina Birükov, M.Sc. Svenja Siewers, M.Sc. Lu Qian, Dr.-Ing. Jedsada Saijai, Dr.-Ing. Ali Abdo, Dr.-Ing. Christoph Kandler, Dr.-Ing. Shane Dominic, Dr. Yuri Shardt, Dr. Yong Zhang, Dr.-Ing. Kai Zhang, Dipl.-Ing. Jonas Esch, M.Sc. Tim Daszenies, M.Sc. Zhiwen Chen, M.Sc. Changchen Xiang, M.Sc. Abdul Latif, M.Sc. Yunsong Xu, M.Sc. Changsheng Hua, M.Sc. Zhengeng Zhao. Special thanks to Prof. Ying Yang, Prof. Hongli Dong, Prof. Zidong Wang, Prof. Bo Shen, Dr. Zhiwei Gao, Prof. Yucai Zhu, Prof. Yaguo Lei, Prof. Kaixiang Peng, Prof. Jianbin Qiu, Prof. Xu Yang for their valuable suggestions and supports during their visits in AKS. My acknowledgement will be incomplete without thanking Mrs. Sabine Bay, Dipl.-Ing. Klaus Göbel, Mr. Ulrich Janzen for their help in organizational responsibilities.

Finally, I would like to thank my parents for their complete understanding and unconditional supports in all my decisions. I cannot finish this work without their love and encouragements.

*To my parents:
Yu Sun and Zhengyuan Luo*

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Nomenclature

The main abbreviations and symbols used in this work are summarized in the following nomenclature. Here, the chosen declaration is based on DIN 1338. All scalar values, physical constants and functions are in italics. Standard mathematical functions and constants are described by letters in normal font. Matrices and vectors are written in bold letters, while vectors are of lowercase letters and matrices are of uppercase letters.

Abbreviations

Abbreviation	Description
AGC	Automatic Gauge Control
ALB	Acceptable Lower Bound
AUB	Acceptable Upper Bound
BLDC	Brushless Direct Current
CAN	Controller Area Network
CL	Component Level
DC	Direct Current
DO	Diagnostic Observer
ECU	Electronic Control Unit
FD	Fault Detection
FDA	Fisher Discriminant Analysis
fdf	Fault Detection Filter
FDI	Fault Detection and Isolation
FDIA	Fault Detection, Isolation and Identification
FFT	Fast Fourier Transform
FTC	Fault-Tolerant Control
FTCA	Fault-Tolerant Control Architecture
GIMC	Generalized Internal Model Control
GM-AGC	Gauge Meter Automatic Gauge Control
HIL	Hardware-in-the-loop
I/O	Input/Output
ICA	Independent Component Analysis
IMC	Internal Model Control
KPI	Key Performance Indicator
LAN	Local Area Network
LB	Lower Bound
LCF	Left Coprime Factorization
LTI	Linear Time-Invariant
MIMO	Multi-Input Multi-Output
MISO	Multi-Input Single-Output
PCA	Principle Component Analysis

Abbreviation	Description
PI	Proportional-Integral
PID	Proportional-Integral-Derivative
PLS	Partial Least Squares
PS	Parity Space
PnP	Plug-and-Play
PnP-PMCA	Plug-and-Play Process Monitoring and Control Architecture
RCF	Right Coprime Factorization
RMS	Root Mean Square
SCADA	Supervisory Control And Data Acquisition
SIM	Subspace Identification Method
SIMO	Single-Input Multi-Output
SIR	Stable Image Representation
SISO	Single-Input Single-Output
SKR	Stable Kernel Representation
SL	System Level
SSL	Subsystem Level
SVD	Singular Value Decomposition
SVM	Support Vector Machine
UB	Upper Bound
w.r.t.	with respect to

Mathematical symbols

Symbol	Description
\in	belong to
\approx	approximately equal
\neq	not equal
$:=$	defined as
\Rightarrow	imply
$\ \cdot\ _2$	\mathcal{L}_2 -norm of a signal
\mathbf{I}_n	an n by n identity matrix
$\mathbf{0}_n$	an n by n zero matrix
\mathcal{R}^n	space of real n -dimensional vectors
\mathbf{A}^T	transpose of \mathbf{A}
$\text{trace}(\mathbf{A})$	trace of \mathbf{A}
$\text{eig}(\mathbf{A})$	eigenvalues of \mathbf{A}
sup	supremum
max (min)	maximum (minimum)
vec	vectorization of a given matrix
\otimes	the Kronecker product

Control theoretical symbols

Symbol	Description
k	discrete-time sample
n	system order
l	number of inputs
m	number of outputs
k_d	number of disturbances
k_f	number of additive faults
\mathbf{u}	input vector
\mathbf{y}	output vector
$\boldsymbol{\omega}$	reference vector
\mathbf{x}	state variable vector
\mathbf{d}	unknown disturbance vector
\mathbf{f}	additive fault vector
$\boldsymbol{\xi}$	process noise vector
\mathbf{v}	measurement noise vector
\mathbf{A}	system matrix
\mathbf{B}	input matrix
\mathbf{C}	output matrix
\mathbf{D}	feed-through matrix
\mathbf{E}_d	disturbance distribution matrix
\mathbf{F}_d	disturbance distribution matrix
\mathbf{E}_f	fault distribution matrix
\mathbf{F}_f	fault distribution matrix
\mathbf{A}_f	faults on system matrix
\mathbf{B}_f	faults on input matrix
\mathbf{C}_f	faults on output matrix
\mathbf{D}_f	faults on feed-through matrix
$\mathbf{G}_{yu}(z)$	discrete-time transfer function matrix from u to y
\mathcal{RH}_∞	set of all proper and real-rational stable transfer matrices
Δ	model uncertainty