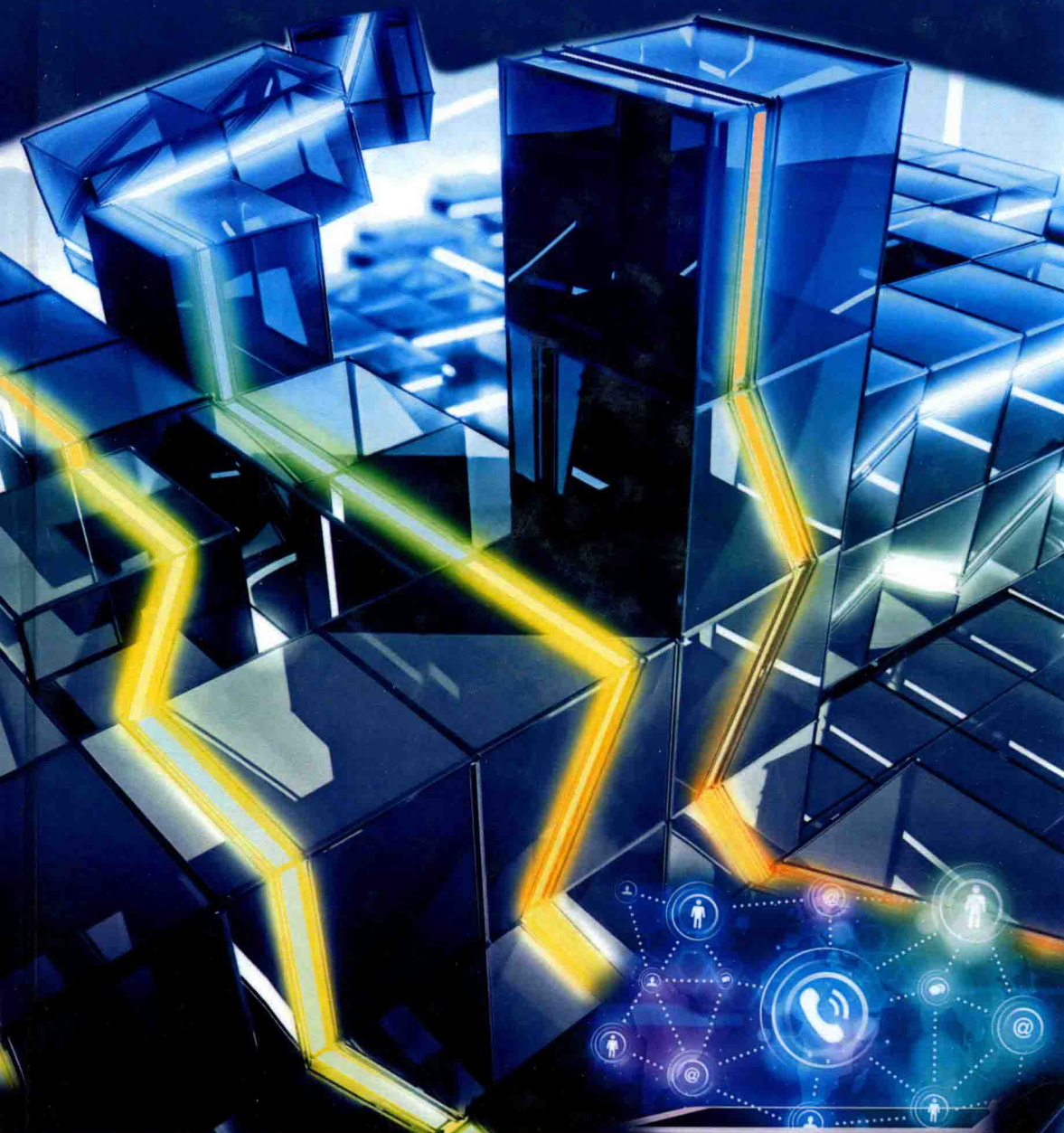


Networked Filtering and Fusion in Wireless Sensor Networks



Magdi S. Mahmoud
Yuanqing Xia

 CRC Press
Taylor & Francis Group

Networks and Fusion in Wireless Sensor Networks

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CRC Press

Taylor & Francis Group

Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

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Printed on acid-free paper
Version Date: 20140728

International Standard Book Number-13: 978-1-4822-5096-1 (Hardback)

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Library of Congress Cataloging-in-Publication Data

Mahmoud, Magdi S.
Networked filtering and fusion in wireless sensor networks / authors, Magdi S.
Mahmoud, Yuanqing Xia.
pages cm
Includes bibliographical references and index.
ISBN 978-1-4822-5096-1 (hardback)
1. Multisensor data fusion. 2. Information filtering systems. I. Xia, Yuanqing. II.
Title.

TK7872.D48M34 2014
004.6--dc23

2014027990

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*To My Loving Wife **Salwa**,
To the “**M**” Family: **Medhat, Monda, Mohamed, Menna and
Malak, Mostafa, Mohamed
and Ahmed Gouda***

MsM

*To My Honest and Diligent Wife **Wang Fangyu**,
To My lovely Daughter **Xia Jingshu***

YX

Notations and Symbols

\mathbb{R}	=	set of real numbers
\mathbb{R}^n	=	set of all n -dimensional real vectors
$\mathbb{R}^{n \times m}$	=	set of $n \times m$ -dimensional real matrices
x^t or A^t	=	transpose of vector x or matrix A
A^{-1}	=	inverse of matrix A
I	=	identity matrix of arbitrary order
e_j	=	j th column of matrix I
$\lambda(A)$	=	eigenvalue of matrix A
$\rho(A)$	=	spectral radius of matrix A
$\lambda_j(A)$	=	j th eigenvalue of matrix A
$\lambda_m(A)$	=	minimum eigenvalue of matrix A where $\lambda(A)$ are real
$\lambda_M(A)$	=	maximum eigenvalue of matrix A where $\lambda(A)$ are real
A^\dagger	=	Moore–Penrose-inverse of matrix A
$P > 0$	=	matrix P is real symmetric and positive-definite
$P \geq 0$	=	matrix P is real symmetric and positive semi-definite
$P < 0$	=	matrix P is real symmetric and negative-definite
$P \leq 0$	=	matrix P is real symmetric and negative semi-definite
$A(i, j), A_{ij}$	=	ij -th element of matrix A
$\det(A)$	=	determinant of matrix A
$\text{trace}(A)$	=	trace of matrix A

$\text{rank}(A)$	=	rank of matrix A
$ a $	=	absolute value of scalar a
$\ x\ $	=	Euclidean norm of vector x
$\ A\ $	=	induced Euclidean norm of matrix A
$\ x\ _p$	=	ℓ_p norm of vector x
$\ A\ _p$	=	induced ℓ_p norm of matrix A

List of Acronyms

<i>ACK</i>	<i>positive acknowledgment</i>
<i>CF</i>	<i>consensus filters</i>
<i>CIM</i>	<i>centralized integration method</i>
<i>CTS</i>	<i>clear to send</i>
<i>DBF</i>	<i>diffusion-based filtering</i>
<i>DC</i>	<i>distributed control</i>
<i>DCF</i>	<i>distributed coordination function</i>
<i>DF</i>	<i>distributed filtering</i>
<i>DIFS</i>	<i>distributed interframe space</i>
<i>DIP</i>	<i>distributed information processing</i>
<i>DMPC</i>	<i>distributed model predictive control</i>
<i>DPF</i>	<i>distributed particle filtering</i>
<i>EKF</i>	<i>extended Kalman filter</i>
<i>EMA</i>	<i>expected maximization algorithm</i>
<i>IUB</i>	<i>industrial utility boiler</i>
<i>LKF</i>	<i>Lyapunov–Krasovskii functional</i>
<i>LMI</i>	<i>linear matrix inequality</i>
<i>MSDF</i>	<i>multi-sensor data fusion</i>
μ KF	<i>micro-Kalman filters</i>
<i>PE</i>	<i>performance evaluation</i>
<i>PKF</i>	<i>partitioned Kalman filter</i>
<i>RTS</i>	<i>request to send</i>
<i>SIFS</i>	<i>short interframe space</i>
<i>SNS</i>	<i>sensor networked systems</i>
<i>STF</i>	<i>self-tuning filtering</i>
<i>WSN</i>	<i>wireless sensor networks</i>

Acknowledgments

We are indebted to the people who made the writing of this book possible. Professor Mahmoud thanks KFUPM management for the continuous encouragement and facilitating all sources of help. Particular appreciation goes to the deanship of scientific research (DSR) for providing a superb competitive environment of research activities through internal funding grants. It is a great pleasure to acknowledge the financial funding afforded by DSR through project no. IN131039 and for providing overall support of research activities at KFUPM. Professor Mahmoud owes a measure of gratitude to the National Natural Science Foundation of China (61225015) for fully sponsoring the technical visit to BIT, China during January–March, 2014.

During the past five years, we had the privilege of teaching various senior and graduate courses. The course notes, updated and organized, were instrumental in generating different chapters of this book, and valuable comments and/or suggestions by graduate students were greatly helpful, particularly those who attended the courses SE 537, SE 652 and SE 658 offered at the Systems Engineering Department over the period 2007–2011.

Most of all, however, we would like to express our deepest gratitude to all the members of our families for their enthusiastic support, without which this volume would not have been finished.

We would appreciate any comments, questions, criticisms, or corrections that readers may kindly provide to Professor Mahmoud at msmahmoud@kfupm.edu.sa or magdisadekmahmoud@gmail.com.

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Preface

In recent years, wireless sensor networks (WSN) have produced a large amount of data that need to be processed, delivered, and assessed according to the application objectives. The way these data are manipulated by the sensor nodes is a fundamental issue. Information fusion arises as a response to process data gathered by sensor nodes and benefits from their processing capability. By exploiting the synergy among the available data, information fusion techniques can reduce the amount of data traffic, filter noisy measurements, and make predictions and inferences about a monitored entity. The book introduces the subject of multi-sensor fusion as the method of choice for implementing distributed systems.

This book is about the current state-of-the-art of information fusion, presenting the known methods, algorithms, architectures, and models of information fusion, and discussing their applicability in the context of wireless sensor networks. Particular considerations are given to covering wide topics that were treated in the literature and presenting results of typical case studies. The key feature is to provide a teaching-oriented volume with research-supported elements and comprehensive references.

The book applies recently developed convex optimization theory and high efficient algorithms in estimation fusion, which opens a very attractive research subject on distributed estimation and fusion for sensor networks. Supplying powerful and advanced mathematical treatment of the fundamental problems, it will help to greatly broaden prospective applications of such developments in practice.

The ultimate vision of this work is that information-based control designers will be able to model parts of dynamic systems (much as control engineers model electrical and mechanical systems), and use those models to develop distributed fusion control algorithms based on a theory of feedback control. It is intended to present a cohesive overview of the key results of theory and applications of information fusion-related problems in networked systems in a unified framework.

Throughout this book, the following terminologies, conventions and notations have been adopted. All of them are quite standard in the scientific media and only vary in form or character. Matrices, if their dimensions are not explicitly stated, are

assumed to be compatible for algebraic operations. In symmetric block matrices or complex matrix expressions, we use the symbol \bullet to represent a term that is induced by symmetry.

Many modern large-scale systems are automatically managed through networks of computers that are tied to sensors and actuators, leading to networked control systems. The inter-relationships among communication, computation, and control in such systems are clearly a subject of great interest. Therefore, networked fusion and filtering are attracting increasing attention in view of their wide industrial implications. The idea for writing the book arose and developed through the consecutive visits of the first author to the second author at the BIT, China. In writing this volume, we took the approach of referring within the text to papers and/or books which we believe taught us some concepts, ideas, and methods. We further complemented this by adding remarks and notes within and at the end of each chapter to shed some light on other related results.

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