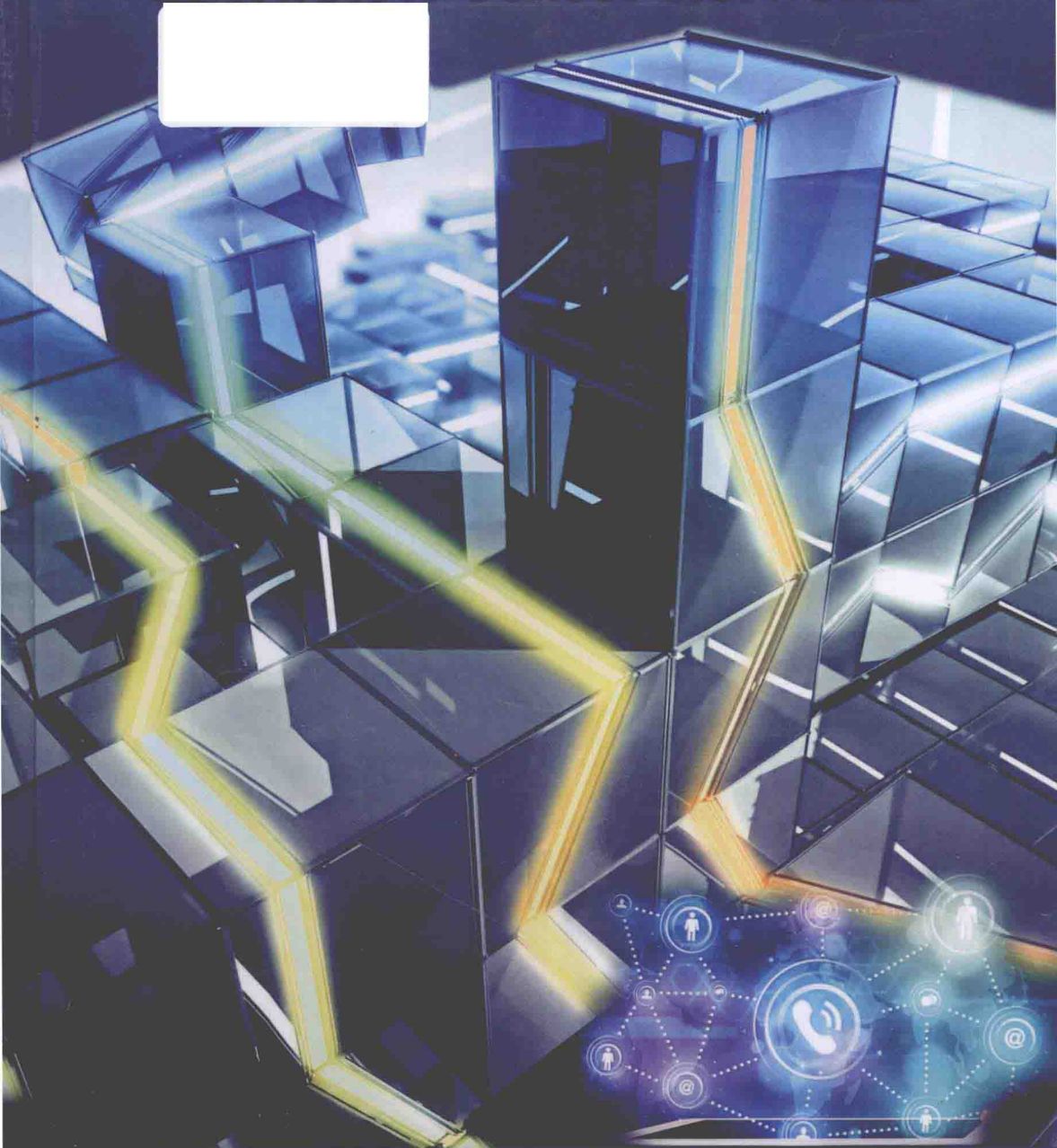


Networked Filtering and Fusion in Wireless Sensor Networks



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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
$\varrho(A)$	=	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

rank (A)	=	<i>rank of matrix A</i>
$ a $	=	<i>absolute value of scalar a</i>
$\ x\ $	=	<i>Euclidean norm of vector x</i>
$\ A\ $	=	<i>induced Euclidean norm of matrix A</i>
$\ x\ _p$	=	<i>ℓ_p norm of vector x</i>
$\ A\ _p$	=	<i>induced ℓ_p norm of matrix A</i>

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>

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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.