PREFACE

Multisensor data fusion is an emerging technology applied to Department of Defense (DoD) areas such as automated target recognition (ATR), identification-friend-foe-neutral (IFFN) recognition systems, battlefield surveillance, and guidance and control of autonomous vehicles. Non-DoD applications include monitoring of complex machinery, environmental surveillance and monitoring systems, medical diagnosis, and smart buildings. Techniques for data fusion are drawn from a wide variety of disciplines, including signal processing, pattern recognition, statistical estimation, artificial intelligence, and control theory. The rapid evolution of computers, proliferation of micro-mechanical/electrical systems (MEMS) sensors, and the maturation of data fusion technology provide a basis for utilization of data fusion in everyday applications.

This book is intended to be a comprehensive resource for data fusion system designers and researchers, providing information on terminology, models, algorithms, systems engineering issues, and examples of applications. The book is divided into four main parts. Part I introduces data fusion terminology and models. Chapter 1 provides a general introduction to data fusion and terminology. Chapter 2 introduces the Joint Directors of Laboratories (JDL) data fusion process model, widely used to assist in understanding DoD applications. In Chapter 3, Jeffrey Uhlmann discusses the problem of multitarget, multisensor tracking and introduces the challenges of data association and correlation. Chapter 4, by Ed Waltz, introduces concepts of image and spatial data fusion, and in Chapter 5 Richard Brooks and Lynne Grewe describe issues of data registration for image fusion. Chapter 6, written by Richard Antony, discusses issues of data fusion focused on situation assessment and database management. Finally, in Chapter 7, Joseph Carl contrasts some approaches to combining evidence using probability and fuzzy set theory.

A perennial problem in multisensor fusion involves combining data from multiple sensors to track moving targets. Gauss originally addressed this problem for estimating the orbits of asteroids by developing the method of least squares. In its most general form, this problem is not tractable. In general, we do not know *a priori* how many targets exist or how to assign observations to potential targets. Hence, we must simultaneously estimate the state (e.g., position and velocity) of N targets based on M sensor reports and also determine which of the M reports belong to (or should be assigned to) each of the N targets. This problem may be complicated by closely spaced, maneuvering targets with potential observational clutter and false alarms.

Part II of this book presents alternative views of this multisensor, multitarget tracking problem. In Chapter 8, T. Kirubarajan and Yaakov Bar-Shalom present an overview of their approach for probabilistic data association (PDA) and the joint PDA (JPDA) methods. These have been useful in dense target tracking environments. In Chapter 9, Jeffrey Uhlmann describes another approach using an approximate method for addressing the data association combination problem. A classical Bayesian approach to target tracking and identification is described by Lawrence D. Stone in Chapter 10. This has been applied to problems in target identification and tracking for undersea vehicles. Recent research by Aubrey B. Poore, Suihua Lu, and Brian J. Suchomel is summarized in Chapter 11. Poore's approach combines the problem of estimation and data association by generalizing the optimization problem, followed by development of efficient computational methods. In Chapter 12, Simon Julier and Jeffrey K. Uhlmann discuss issues related to the estimation of target error and how to treat the codependence between sensors. They extend this work to nonlinear systems in Chapter 13. Finally, in Chapter 14, Ronald Mahler provides a very extensive discussion of multitarget, multisensor tracking using an approach based on random set theory.

Part III of this book addresses issues of the design and development of data fusion systems. It begins with Chapter 15 by Ed Waltz and David L. Hall, and describes a systemic approach for deriving data fusion system requirements. Chapter 16 by Christopher Bowman and Alan Steinberg provides a general discussion of the systems engineering process for data fusion systems including the selection of appropriate architectures. In Chapter 17, David L. Hall, James Llinas, Christopher L. Bowman, Lori McConnel, and Paul Applegate provide engineering guidelines for the selection of data fusion algorithms. In Chapter 18, Richard Antony presents a discussion of database management support, with applications to tactical data fusion. New concepts for designing human-computer interfaces (HCI) for data fusion systems are summarized in Chapter 19 by Mary Jane Hall, Sonya Hall, and Timothy Tate. Performance assessment issues are described by James Llinas in Chapter 20. Finally, in Chapter 21, David L. Hall and Alan N. Steinberg present the *dirty secrets* of data fusion. The experience of implementing data fusion systems described in this section was primarily gained on DoD applications; however, the lessons learned should be of value to system designers for any application.

Part IV of this book provides a taste of the breadth of applications to which data fusion technology can be applied. Mary L. Nichols, in Chapter 22, presents a limited survey of some DoD fusion systems. In Chapter 23, Carl S. Byington and Amulya K. Garga describe the use of data fusion to improve the ability to monitor complex mechanical systems. Robert J. Hansen, Daniel Cooke, Kenneth Ford, and Steven Zornetzer provide an overview of data fusion applications at the National Aeronautics and Space Administration (NASA) in Chapter 24. In Chapter 25, Richard R. Brooks describes an application of data fusion funded by DARPA. Finally, in Chapter 26, Hans Keithley describes how to determine the utility of data fusion for C4ISR. This fourth part of the book is not by any means intended to be a comprehensive survey of data fusion applications. Instead, it is included to provide the reader with a sense of different types of applications. Finally, Part V of this book provides a list of Internet Web sites and news groups related to multisensor data fusion.

The editors hope that this handbook will be a valuable addition to the bookshelves of data fusion researchers and system designers. We remind the reader that data fusion remains an evolving discipline. Even for classic problems, such as multisensor, multitarget tracking, competing approaches exist. The book has sought to identify and provide a representation of the leading methods in data fusion. The reader should be advised, however, that there are disagreements in the data fusion community (especially by some of the contributors to this book) concerning which method is *best*. It is interesting to read the descriptions that the authors in this book present concerning the relationship between their own techniques and those of the other authors. Many of this book's contributors have written recent texts that advocate a particular method. These authors have condensed or summarized that information as a chapter here.

We take the view that each competing method must be considered in the context of a specific application. We believe that there is no such thing as a generic data fusion system. Instead, there are numerous applications to which data fusion techniques can be applied. In our view, there is no such thing as a magic approach or technique. Even very sophisticated algorithms may be corrupted by a lack of *a priori* information or incorrect information concerning sensor performance. Thus, we advise the reader to become a knowledgeable and demanding consumer of fusion algorithms.

We hope that this text will become a companion to other texts on data fusion methods and techniques, and that it assists the data fusion community in its continuing maturation process.