Sensor and Data Fusion

A Tool for Information Assessment and Decision Making

SECOND EDITION

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To Jonathan, Amy, Gregory,

Maya, Theo, Cassie, and Tessa

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Preface

Sensor and Data Fusion: A Tool for Information Assessment and Decision Making, Second Edition is the latest embodiment of a series of books I have published with SPIE beginning in 1993. The information in this edition has been substantially expanded and updated to incorporate additional sensor and data fusion methods and application examples.

The book serves as a companion text to courses taught by the author on multi-sensor, multi-target data fusion techniques for tracking and identification of objects. Material discussing the benefits of multi-sensor systems and data fusion originally developed for courses on advanced sensor design for defense applications was utilized in preparing the original edition. Those topics that deal with applications of multiple-sensor systems; target, background, and atmospheric signature-generation phenomena and modeling; and methods of combining multiple-sensor data in target identity and tracking data fusion architectures were expanded for this book. Most signature phenomena and data fusion techniques are explained with a minimum of mathematics or use relatively simple mathematical operations to convey the underlying principles. Understanding of concepts is aided by the nonmathematical explanations provided in each chapter.

Multi-sensor systems are frequently deployed to assist with civilian and defense applications such as weather forecasting, Earth resource monitoring, traffic and transportation management, battlefield assessment, and target classification and tracking. They can be especially effective in defense applications where volume constraints associated with smart-weapons design are of concern and where combining and assessing information from noncollocated or dissimilar sensors and other data sources is critical. Packaging volume restrictions associated with the construction of fire-and-forget missile systems often restrict sensor selection to those operating at infrared and millimeter-wave frequencies. In addition to having relatively short wavelengths and hence occupying small volumes, these sensors provide high resolution and complementary information as they respond to different signature-generation phenomena. The result is a large degree of immunity to inclement weather, clutter, and signature masking produced by countermeasures. Sensor and data fusion architectures enable the information from the sensors to be combined in an efficient and effective manner.

High interest continues in defense usage of data fusion to assist in the identification of missile threats and other strategic and tactical targets, assessment of information, evaluation of potential responses to a threat, and allocation of resources. The signature-generation phenomena and fusion architectures and algorithms presented continue to be applicable to these areas and the growing number of nondefense applications.

The book chapters provide discussions of the benefits of infrared and millimeter-wave sensor operation including atmospheric effects; multiple-sensor system applications; and definitions and examples of sensor and data fusion architectures and algorithms. Data fusion algorithms discussed in detail include classical inference, which forms a foundation for the more general Bayesian inference and Dempster–Shafer evidential theory that follow; artificial neural networks; voting logic as derived from Boolean algebra expressions; fuzzy logic; and Kalman filtering. Descriptions are provided of multiple-radar tracking systems and architectures, and detection and tracking of objects using only passively acquired data. The book concludes with a summary of the information required to implement each of the data fusion methods discussed.

Although I have strived to keep the mathematics as simple as possible and to include derivations for many of the techniques, a background in electrical engineering, physics, or mathematics will assist in gaining a more complete understanding of several of the data fusion algorithms. Specifically, knowledge of statistics, probability, matrix algebra, and to a lesser extent, linear systems and radar detection theory are useful.

Several people have made valuable suggestions that were incorporated into this edition. Martin Dana, with whom I taught the multi-sensor, multi-target data fusion course, reviewed several of the newer sections and contributed heavily to Chapter 10 dealing with multiple-sensor radar tracking and architectures. His insightful suggestions have improved upon the text. Henry Heidary, in addition to his major contributions to Chapter 11, reviewed other sections of the original manuscript. Sam Blackman reviewed the original text and provided several references for new material that was subsequently incorporated. Pat Williams reviewed sections on tracking and provided data concerning tracking-algorithm execution times. Tim Lamkins, Scott McNeill, Eric Pepper, and the rest of the SPIE staff provided technical and editorial assistance that improved the quality of the text.

Lawrence A. Klein

August 2012