Tracking And Data Fusion A Handbook Of Algorithms By

This volume presents the state-of-the-art in advanced radar, with emphasis on ongoing novel research and development and contributions from an international team of leading radar experts.
A new approach is taken to address the various aspects of the multi-sensor, multi-target tracking (MTT) problem in dense and noisy environments. Instead of fixing the trackers on the potential targets as the conventional tracking algorithms do, this new approach is fundamentally different in that an array of parallel-distributed trackers is laid in the search space. The difficult data-track association problem that has challenged the conventional trackers becomes a nonissue with this new approach. By partitioning the search space into cells, this new approach, called PMAP (probabilistic mapping), dynamically calculates the spatial probability distribution of targets in the search space via Bayesian updates. The distribution is spread at each time step, following a fairly general Markov-chain target motion model, to become the prior probabilities of the next scan. This framework can effectively handle data from multiple sensors and incorporate contextual information, such as terrain and weather, by performing a form of evidential reasoning. Used as a pre-filtering device, the PMAP is shown to remove noiselike false alarms effectively, while keeping the target dropout rate very low. This gives the downstream track linker a much easier job to perform. A related benefit is that with PMAP it is now possible to lower the detection threshold and to enjoy high probability of detection and low probability of false alarm at the same time, thereby improving overall tracking performance. The feasibility of using PMAP to track specific targets in an end-game scenario is also demonstrated. Both real and simulated data are used to illustrate the PMAP performance. The PMAP algorithm is parallel distributed in nature; for serial computer implementation, fast algorithms have been developed. Some related applications based on the PMAP approach, including a spatial-temporal sensor data fusion application and a gray-scale video sequence stacking application, are also discussed.
Data Fusion Performance Evaluation for Dissimilar Sensors: Application to Road Obstacle Tracking.
Multi-Sensor Data Fusion
Tracking and Data Fusion Applications
Multitarget Multisensor Tracking for Data Fusion
Target Tracking and Data Fusion (Digest No: 1996
Waveform Diversity and Cognitive Radar and Target Tracking and Data Fusion, Volume 2
Multisensor Data Fusion

Fills the Existing Gap of Mathematics for Data Fusion Data fusion (DF) combines large amounts of information from a variety of sources and fuses this data algorithmically, logically and, if required intelligently, using artificial intelligence (AI). Also, known as sensor data fusion (SDF), the DF fusion system is an important component for use in various applications that include the monitoring of vehicles, aerospace systems, large-scale structures, and large industrial automation plants. Data Fusion Mathematics: Theory and Practice offers a comprehensive overview of data fusion, and provides a proper and adequate understanding of the basic mathematics directly related to DF. The material covered can be used for evaluation of the performances of any designed and developed DF systems. It tries to answer whether unified data fusion mathematics can evolve from various disparate mathematical concepts, and highlights mathematics that can add credibility to the data fusion process. Focuses on Mathematical Tools That Use Data Fusion This text explores the use of statistical/probabilistic signal/image processing, filtering, component analysis, image algebra, decision making, and neuro-FL–GA paradigms in studying, developing and validating data fusion processes (DFP). It covers major mathematical expressions, and formulae and equations as well as, where feasible, their derivations. It also discusses SDF concepts, DF models and architectures, aspects and methods of type 1 and 2 fuzzy logics, and related practical applications. In addition, the author covers soft computing paradigms that are finding increasing applications in multisensory DF approaches and applications. This book: Explores the use of interval type 2 fuzzy logic and ANFIS in DF Covers the mathematical treatment of many types of filtering algorithms, target-tracking methods, and kinematic DF methods Presents single and multi-sensor tracking and fusion mathematics Considers specific DF architectures in the context of decentralized systems Discusses information filtering, Bayesian approaches, several DF rules, image algebra and image fusion, decision fusion, and wireless sensor network (WSN) multimodality fusion Data Fusion Mathematics: Theory and Practice incorporates concepts, processes, methods, and approaches in data fusion that can help you with integrating DF mathematics and achieving higher levels of fusion activity, and clarity of performance. This text is geared toward researchers, scientists, teachers and practicing engineers interested and working in the multisensor data fusion area.
Research on multisensor data fusion aims at providing the enabling technology to combine information from several sources in order to form a unifi ed picture. The literature work on fusion of conventional data provided by non-human (hard) sensors is vast and well-established. In comparison to conventional fusion systems where input data are generated by calibrated electronic sensor systems with well-defi ned characteristics, research on soft data fusion considers combining human-based data expressed preferably in unconstrained natural language form. Fusion of soft and hard data is even more challenging, yet necessary in some applications, and has received little attention in the past. Due to being a rather new area of research, soft/hard data fusion is still in a edging stage with even its challenging problems yet to be adequately de fined and explored. This dissertation develops a framework to enable fusion of both soft and hard data with the Random Set (RS) theory as the underlying mathematical foundation. Random set theory is an emerging theory within the data fusion community that, due to its powerful representational and computational capabilities, is gaining more and more attention among the data fusion researchers. Motivated by the unique characteristics of the random set theory and the main challenge of soft/hard data fusion systems, i.e. the need for a unifying framework capable of processing both unconventional soft data and conventional hard data, this dissertation argues in favor of a random set theoretic approach as the first step towards realizing a soft/hard data fusion framework. Several challenging problems related to soft/hard fusion systems are addressed in the proposed framework. First, an extension of the well-known Kalman lter within random set theory, called Kalman evidential filter (KEF), is adopted as a common data processing framework for both soft and hard data. Second, a novel ontology (syntax+semantics) is developed to allow for modeling soft (human-generated) data assuming target tracking as the application. Third, as soft/hard data fusion is mostly aimed at large networks of information processing, a new approach is proposed to enable distributed estimation of soft, as well as hard data, addressing the scalability requirement of such fusion systems. Fourth, a method for modeling trust in the human agents is developed, which enables the fusion system to protect itself from erroneous/misleading soft data through discounting such data on-the-fly. Fifth, leveraging the recent developments in the RS theoretic data fusion literature a novel soft data association algorithm is developed and deployed to extend the proposed target tracking framework into multi-target tracking case. Finally, the multi-target tracking framework is complemented by introducing a distributed classi fication approach applicable to target classes described with soft human-generated data. In addition, this dissertation presents a novel data-centric taxonomy of data fusion methodologies. In particular, several categories of fusion algorithms have been identifi ed and discussed based on the data-related challenging aspect(s) addressed. It is intended to provide the reader with a generic and comprehensive view of the contemporary data fusion literature, which could also serve as a reference for data fusion practitioners by providing them with conducive design guidelines, in terms of algorithm choice, regarding the specifi c data-related challenges expected in a given application.
With the recent proliferation of service-oriented architectures (SOA), cloud computing technologies, and distributed-interconnected systems, distributed fusion is taking on a larger role in a variety of applications—from environmental monitoring and crisis management to intelligent buildings and defense. Drawing on the work of leading experts around the world, Distributed Data Fusion for Network-Centric Operations examines the state of the art of data fusion in a distributed sensing, communications, and computing environment. Get Insight into Designing and Implementing Data Fusion in a Distributed Network Addressing the entirety of information fusion, the contributors cover everything from signal and image processing, through estimation, to situation awareness. In particular, the work offers a timely look at the issues and solutions involving fusion within a distributed network enterprise. These include critical design problems, such as how to maintain a pedigree of agents or nodes that receive information, provide their contribution to the dataset, and pass to other network components. The book also tackles dynamic data sharing within a network-centric enterprise, distributed fusion effects on state estimation, graph-theoretic methods to optimize fusion performance, human engineering factors, and computer ontologies for higher levels of situation assessment. A comprehensive introduction to this emerging field and its challenges, the book explores how data fusion can be used within grid, distributed, and cloud computing architectures. Bringing together both theoretical and applied research perspectives, this is a valuable reference for fusion researchers and practitioners. It offers guidance and insight for those working on the complex issues of designing and implementing distributed, decentralized information fusion.
Sensor and Data Fusion
Multitarget-multisensor Tracking

Methodological Framework and Selected Applications
Data Fusion: Concepts and Ideas
Data Fusion Performance Evaluation For Dissimilar Sensors

The book explores object and situation fusion processes with an appropriate handling of uncertainties, and applies cutting-edge artificial intelligence and emerging technologies like particle filtering, spatiotemporal clustering, net-centricity, agent formalism, and distributed fusion together with essential Level 1 techniques and Level 1/2 interactions.
Current data fusion architectures are evolving from single-platform, standalone systems to multi-platform, integrated systems. By taking advantage of the favorable geometry of a distributed data fusion system, target tracking performance can be greatly increased. Sensors can typically provide an estimation of a target's position, but only the radial component of the target's velocity. The target's velocity is typically obtained by tracking a target over time and estimating both position and velocity by putting the correlated sensor reports through a kalman filter. This filtering can take on the order of minutes (depending on sensor update rates) in which time the target may have maneuvered, possibly causing the filtering process to restart. If the range rate information from multiple platforms is combined, target velocity can be estimated quicker and with greater accuracy. This velocity information can then be fed back to the individual platforms, allowing smaller correlation gates which will enable tracking in higher density scenarios. The drawback to this approach is an increase in the amount of data that needs to be communicated among the platforms. This paper considers the performance implications of four different multi-platform architectures: sharing the best track, fusing all of the tracks, fusing all of the sensor reports, and fusing sensor reports that contain range rate information. The metrics that will analyzed are: track initiation time, velocity accuracy, and communication message bandwidth.
Data fusion or information fusion are names which have been primarily assigned to military-oriented problems. In military applications, typical data fusion problems are: multisensor, multitarget detection, object identification, tracking, threat assessment, mission assessment and mission planning, among many others. However, it is clear that the basic underlying concepts underlying such fusion procedures can often be used in nonmilitary applications as well. The purpose of this book is twofold: First, to point out present gaps in the way data fusion problems are conceptually treated. Second, to address this issue by exhibiting mathematical tools which treat combination of evidence in the presence of uncertainty in a more systematic and comprehensive way. These techniques are based essentially on two novel ideas relating to probability theory: the newly developed fields of random set theory and conditional and relational event algebra. This volume is intended to be both an update on research progress on data fusion and an introduction to potentially powerful new techniques: fuzzy logic, random set theory, and conditional and relational event algebra. Audience: This volume can be used as a reference book for researchers and practitioners in data fusion or expert systems theory, or for graduate students as text for a research seminar or graduate level course.
Target Tracking and Data Fusion (Digest No
Multi-sensor Multi-target Data Fusion, Tracking and Identification Techniques for Guidance and Control Applications
An Introduction
Target Tracking and Data Fusion in a Multisensor Environment
Multiple-Target Tracking and Data Fusion Via Probabilistic Mapping
Theory and Practice

In recent years, many researchers have investigated automated progress tracking for construction projects. These efforts range from 2D photo-feature extraction to 3D laser scanners and radio frequency identification (RFID) tags. A multi-sensor data fusion model that utilizes multiple sources of information would provide a better alternative than a single-source model for tracking project progress. However, many existing fusion models are based on data fusion at the sensor and object levels and are therefore incapable of capturing critical information regarding a number of activities and processes on a construction site, particularly those related to non-structural trades such as welding, inspection, and installation activities. In this research, a workflow based data fusion framework is developed for construction progress, quality and productivity assessment.
Tracking and Data FusionA Handbook of AlgorithmsTracking and Sensor Data FusionMethodological Framework and Selected ApplicationsSpringer Science & Business Media
Expert coverage of the design and implementation of stateestimation algorithms for tracking and navigation Estimation with Applications to Tracking and Navigationtreats the estimation of various quantities from inherentlyinaccurate remote observations. It explains state estimator designusing a balanced combination of linear systems, probability, andstatistics. The authors provide a review of the necessary backgroundmathematical techniques and offer an overview of the basic conceptsin estimation. They then provide detailed treatments of all themajor issues in estimation with a focus on applying thesetechniques to real systems. Other features include: Problems that apply theoretical material to real-worldapplications In-depth coverage of the Interacting Multiple Model (IMM)estimator Companion DynaEst(TM) software for MATLAB(TM) implementation ofKalman filters and IMM estimators Design guidelines for tracking filters Suitable for graduate engineering students and engineers workingin remote sensors and tracking, Estimation with Applications toTracking and Navigation provides expert coverage of thisimportant area.
Target Tracking and Data Fusion
Distributed Random Set Theoretic Soft/hard Data Fusion
Algorithms and Applications, 2008 IET Seminar on
Target Tracking and Data Fusion (Digest No. 1998/282), IEE Colloquium on
Theory Algorithms and Software
High-Level Data Fusion

The goal of this report is to conduct an exhaustive formal literature survey on multisensor data fusion and use the results to conduct performance analyses of the following sensor data fusion subjects: sensor data association & fusion architectures; data association; data fusion; data alignment or registration; target attribute estimation & fusion; application of artificial intelligence techniques; target state estimation analysis; and target model (type of maneuver) identification analysis. The different analysis approaches published in the surveyed literature are identified for each of the above subjects, and relative merits and trade-offs between these approaches are evaluated. The analyses focus on those approaches which could be pertinent to a naval platform employing dissimilar and non-imaging sensors. Includes glossary.
This thesis investigates the improvements that can be made to Bayesian passive sonar tracking in the context of active-passive sonar data fusion. Performance improvements are achieved by exploiting the prior information available within a typical Bayesian data fusion framework. The algorithms developed are tested against both simulated data and data measured during the SEABAR 07 sea trial. Results show that the proposed approaches achieve improved detection, decreased estimation error, and the ability to track quiet targets in the presence of loud interferers.
The Acoustic Signal Processing Branch of the U.S. Army Research Laboratory (ARL) is carrying on research into Battlefield target localization and tracking. To support the development and evaluation of new hardware and algorithms, ARL developed the Data Fusion Testbed and Tracking System (DFTTS). The DFTTS is a research and evaluation tool that enables researchers involved in developing sensors, localization, target detection, identification, and tracking algorithms to quickly evaluate their performance in a real-time environment. The DFTTS provides the necessary software and hardware backbone to support research and development efforts. Its major components are Sensor Signal Processing Nodes (SSPN) that can simultaneously host multiplet sensor technologies and algorithms, along with a second-level Data Fusion Gateway Node (DFGN), which fuses SSPN data and data from other high-level sensor packages. This backbone allows new efforts to focus solely on algorithm and/or hardware development and minimize integration issues and time to in-field demonstration. Its architecture design is based on a distributed-multiprocessor, multitasked system. The design emphasizes a network of independent hardware and software processing modules, interconnected by loosely coupled communication links. This allows for such capabilities as real time comparisons of multiple detection and tracking algorithms and future upgrades of communication links. Since the DFTTS is a research and development tool, it includes methods for adjusting and tuning the system during its operational state and for monitoring of sensor data in real-time. This allows for on-the-fly experimentation with new software algorithms and hardware devices without the need to rebuild the system from the ground up. It also enables diagnostics to be performed on the system, so that the developer can make intelligent decisions about the functional validity of the software and hardware being tested and developed.
Principles and Techniques
Colloqium
A Tool for Information Assessment and Decision Making
Estimation with Applications to Tracking and Navigation
Unified Data Fusion Applied to Monopulse Tracking
Using Target Range Rate Data in Distributed Data Fusion Systems

Using MATLAB® examples wherever possible, Multi-Sensor Data Fusion with MATLAB explores the three levels of multi-sensor data fusion (MSDF): kinematic-level fusion, including the theory of DF; fuzzy logic and decision fusion; and pixel- and feature-level image fusion. The authors elucidate DF strategies, algorithms, and performance evaluation mainly for aerospace applications, although the methods can also be applied to systems in other areas, such as biomedicine, military defense, and environmental engineering. After presenting several useful strategies and algorithms for DF and tracking performance, the book evaluates DF algorithms, software, and systems. It next covers fuzzy logic, fuzzy sets and their properties, fuzzy logic operators, fuzzy propositions/rule-based systems, an inference engine, and defuzzification methods. It develops a new MATLAB graphical user interface for evaluating fuzzy implication functions, before using fuzzy logic to estimate the unknown states of a dynamic system by processing sensor data. The book then employs principal component analysis, spatial frequency, and wavelet-based image fusion algorithms for the fusion of image data from sensors. It also presents procedures for combing tracks obtained from imaging sensor and ground-based radar. The final chapters discuss how DF is applied to mobile intelligent autonomous systems and intelligent monitoring systems. Fusing sensors' data can lead to numerous benefits in a system's performance. Through real-world examples and the evaluation of algorithmic results, this detailed book provides an understanding of MSDF concepts and methods from a practical point of view. Select MATLAB programs are available for download on www.crcpress.com
Data Fusion is a very broad interdisciplinary technology domain. It provides techniques and methods for; integrating information from multiple sources and using the complementarities of these detections to derive maximum information about the phenomenon being observed; analyzing and deriving the meaning of these observations and predicting possible consequences of the observed state of the environment; selecting the best course of action; and controlling the actions. Here, the focus is on the more mature phase of data fusion, namely the detection and identification / classification of phenomena being observed and exploitation of the related methods for Security-Related Civil Science and Technology (SST) applications. It is necessary to; expand on the data fusion methodology pertinent to Situation Monitoring, Incident Detection, Alert and Response Management; discuss some related Cognitive Engineering and visualization issues; provide an insight into the architectures and methodologies for building a data fusion system; discuss fusion approaches to image exploitation with emphasis on security applications; discuss novel distributed tracking approaches as a necessary step of situation monitoring and incident detection; and provide examples of real situations, in which data fusion can enhance incident detection, prevention and response capability. In order to give a logical presentation of the data fusion material, first the general concepts are highlighted (Fusion Methodology, Human Computer Interactions and Systems and Architectures), closing with several applications (Data Fusion for Imagery, Tracking and Sensor Fusion and Applications and Opportunities for Fusion).
Resumé på fransk.
Data Fusion and Tracking System Testbed
1996/253), IEE Colloquium on
A Handbook of Algorithms

Data Fusion Mathematics
Multi-Sensor Data Fusion with MATLAB®
Tuesday, 9 June 1998

Sensor Data Fusion is the process of combining incomplete and imperfect pieces of mutually complementary sensor information in such a way that a better understanding of an underlying real-world phenomenon is achieved. Typically, this insight is either unobtainable otherwise or a fusion result exceeds what can be produced from a single sensor output in accuracy, reliability, or cost. This book provides an introduction Sensor Data Fusion, as an information technology as well as a branch of engineering science and informatics. Part I presents a coherent methodological framework, thus providing the prerequisites for discussing selected applications in Part II of the book. The presentation mirrors the author's views on the subject and emphasizes his own contributions to the development of particular aspects. With some delay, Sensor Data Fusion is likely to develop along lines similar to the evolution of another modern key technology whose origin is in the military domain, the Internet. It is the author's firm conviction that until now, scientists and engineers have only scratched the surface of the vast range of opportunities for research, engineering, and product development that still waits to be explored: the Internet of the Sensors.

Multisensor Data Fusion: From Algorithms and Architectural Design to Applications covers the contemporary theory and practice of multisensor data fusion, from fundamental concepts to cutting-edge techniques drawn from a broad array of disciplines. Featuring contributions from the world’s leading data fusion researchers and academicians, this authoritative book: Presents state-of-the-art advances in the design of multisensor data fusion algorithms, addressing issues related to the nature, location, and computational ability of the sensors Describes new materials and achievements in optimal fusion and multisensor filters Discusses the advantages and challenges associated with multisensor data fusion, from extended spatial and temporal coverage to imperfection and diversity in sensor technologies Explores the topology, communication structure, computational resources, fusion level, goals, and optimization of multisensor data fusion system architectures Showcases applications of multisensor data fusion in fields such as medicine, transportation's traffic, defense, and navigation Multisensor Data Fusion: From Algorithms and Architectural Design to Applications is a robust collection of modern multisensor data fusion methodologies. The book instills a deeper understanding of the basics of multisensor data fusion as well as a practical knowledge of the problems that can be faced during its execution.

The direction of arrival (DOA) computed from the monopulse ratio is known to fluctuate widely in the presence of multiple unresolved targets. This confounds traditional trackers operating on unresolved targets, leading to erroneous state estimates or loss of track. This paper presents a computationally feasible solution to this problem using Metron s Unified Theory of Data Fusion (UDF). UDF is a Bayesian method that maintains a probability density on the joint target state space. It operates without explicitly enumerating multiple data-totarget associations. This is particularly important for unresolved targets where the data cannot be attributed to a single target. Likelihood functions for two Rayleigh targets over a range of SNRs are examined first to develop insight. The final example presents the application to tracking two low-SNR targets crossing the radar beam.

Tracking and Data Fusion
Investigations on Target Tracking and Classification Using Multiple Sensor Data Fusion, Task II:
Design and Analysis of Modern Tracking Systems
Application To Road Obstacle Tracking
Survey and Study of Multiple Sensor Date Fusion Architecture and Techniques : Technical Report -- Rev
Data Fusion for Situation Monitoring, Incident Detection, Alert and Response Management

The emerging technology of multisensor data fusion has a wide range of applications, both in Department of Defense (DoD) areas and in the civilian arena. The techniques of multisensor data fusion draw from an equally broad range of disciplines, including artificial intelligence, pattern recognition, and statistical estimation. With the rapid evolut

This textbook provides a comprehensive introduction to the concepts and idea of multisensor data fusion. It is an extensively revised second edition of the author's successful book: "Multi-Sensor Data Fusion: An Introduction" which was originally published by Springer-Verlag in 2007. The main changes in the new book are: New Material: Apart from one new chapter there are approximately 30 new sections, 50 new examples and 100 new references. At the same time, material which is out-of-date has been eliminated and the remaining text has been rewritten for added clarity. Altogether, the new book is nearly 70 pages longer than the original book. Matlab code: Where appropriate we have given details of Matlab code which may be downloaded from the worldwide web. In a few places, where such code is not readily available, we have included Matlab code in the body of the text. Layout. The layout and typography has been revised. Examples and Matlab code now appear on a gray background for easy identification and advancd material is marked with an asterisk. The book is intended to be self-contained. No previous knowledge of multi-sensor data fusion is assumed, although some familarity with the basic tools of linear algebra, calculus and simple probability is recommended. Although conceptually simple, the study of mult-sensor data fusion presents challenges that are unique within the education of the electrical engineer or computer scientist. To become competent in the field the student must become familiar with tools taken from a wide range of diverse subjects including: neural networks, signal processing, statistical estimation, tracking algorithms, computer vision and control theory. All too often, the student views multi-sensor data fusion as a miscellaneous assortment of different processes which bear no relationship to each other. In contrast, in this book the processes are unified by using a common statistical framework. As a consequence, the underlying pattern of relationships that exists between the different methodologies is made evident. The book is illustrated with many real-life examples taken from a diverse range of applications and contains an extensive list of modern references.

This book addresses the techniques for modeling and integration of data provided by different sensors within robotics and knowledge sources within machine intelligence. Leaders in robotics and machine intelligence capture state-of-the-art technology in data sensor fusion and give a unified vision of the future of the field, presented from both the theoretical and practical angles.

Activity-based Data Fusion for the Automated Progress Tracking of Construction Projects
From Algorithms and Architectural Design to Applications
Bayesian Passive Sonar Tracking in the Context of Active-passive Data Fusion
Tracking and Sensor Data Fusion
New Results in Distributed Detection and Data Fusion for Target Tracking
Distributed Data Fusion for Network-Centric Operations

Here's a thorough overview of the state-of-the-art in design and implementation of advanced tracking for single and multiple sensor systems. This practical resource provides modern system designers and analysts with in-depth evaluations of sensor management, kinematic and attribute data processing, data association, situation assessment, and modern tracking and data fusion methods as applied in both military and non-military arenas.

This book illustrates the benefits of sensor fusion by considering the characteristics of infrared, microwave, and millimeter-wave sensors, including the influence of the atmosphere on their performance. Applications that benefit from this technology include: vehicular traffic management, remote sensing, target classification and tracking- weather forecasting- military and homeland defense. Covering data fusion algorithms in detail, Klein includes a summary of the information required to implement each of the algorithms discussed, and outlines system application scenarios that may limit sensor size but that require high resolution data.

This textbook provides a comprehensive introduction to the theories and techniques of multi-sensor data fusion. It is aimed at advanced undergraduate and first-year graduate students in electrical engineering and computer science, as well as researchers and professional engineers. The book is intended to be self-contained. No previous knowledge of multi-sensor data fusion is assumed, although some familiarity with the basic tools of linear algebra, calculus and simple probability theory is recommended.

Mathematics of Data Fusion
Novel Radar Techniques and Applications
Data Fusion in Robotics & Machine Intelligence