MULTI SENSOR DATA FUSION

by Edward Waltz and James Llinas,
Artech House Radar Library, ISBN: 0-89006-277-3, 464 pages, 1990

This book is devoted to a rapidly developing area of research and development, which involves significant integration of a number of research disciplines. The initial acquaintance with multisensor data fusion technology surprisingly involves more interdisciplinary relations than expected. Communications and decision theories are related to epistemology and uncertainty management. Estimation theory, digital signal processing and computer science are applied in parallel with artificial intelligence.

The book gives a thorough introduction into the taxonomy of functional architectures of the multisensor data fusion systems and defense applications. Contemporary sensors, sources and communications links are presented and sensor management is depicted. Data fusion for state estimation is separately discussed in the context of target tracking applications. An important part of the book covers military concepts of situation and threat assessment. The discussion on implementation approaches for situation and threat assessment is very useful for all specialists working in this area. They will find in the book data fusion system architecture design guidelines, how to model such systems and how to evaluate their performance. The emerging role of artificial intelligence techniques is also presented.

This book is an important introduction to multisensor data fusion technology and its application in military command, control, and intelligence operations. The presentation is given at a system-level. It could be useful to all specialists working in the area of data fusion and C^4I systems development.

INFORMATION WARFARE PRINCIPLES AND OPERATIONS

by Edward Waltz

Artech House Radar Library, ISBN: 0-89006-511-X, 380 pages, 1998

The book presents a system engineering-level introduction in the field of Information Warfare. It provides an overview of the emerging threats in the information space to commercial, civil, and military information systems. It describes how these threats can be identified and how contemporary C^4I systems can be protected.

An important part of the book is devoted to a detailed consideration of components, principles, technologies, and tactics of the information warfare. Three areas critical to success are studied: Information Dominance, Information Defense, and Information Offense. Their comprehensive discussion provides engineers, system operators and information technology users with an understandable overview of the quantification of information, and with deductive and inductive processes that create knowledge. An essential technical background in data mining is given here. All information security technologies are thoroughly discussed including encryption, authorization, and attack detection. In addition, possible information attack technologies, including physical, infrastructure, and perceptual methods, are also analyzed. The book could be of interest for all specialists working in the area of C^4I systems development, as well as to students of information warfare and information operations.

BAYESIAN MULTIPLE TARGET TRACKING

by Lawrence D. Stone, Carl A. Barlow, Thomas L. Corwin,
Artech House Radar Library, ISBN: 1580530249, 300 pages, October 1999

The book is devoted to one of the currently most popular areas of theory and practice – *Multiple Target Tracking*. The well known problem in this area is related to the significant uncertainty in regard to the relevance of the used stochastic models, and the correctness of their application for target position and motion prediction over time. Most of the up-to-date target tracking approaches result in algorithms, which are effective in presence of high amount of data and significant rates of their accumulation. Unfortunately, very often in reality this is not the case. Facing real world problems, the authors focus their attention on the case of low data collecting rates and low signal-to-noise ratio, which is the most wide spread situation currently.

Having in mind that in electronic warfare environments most of the sensors provide ambiguous information about the number of targets and their state, the authors propose Bayesian inference approach as basic theoretical framework for design and development of effective tracking algorithms. Following this path, a general solution of the tracking problems in conditions of insufficient sensor resources is developed. Thus, the use of Bayesian inference framework provides a base for successful design and development of mathematically sound algorithms for dealing with up-to-date tracking problems involving multiple closely spaced targets, multiple netted sensors, and multiple moving platforms. Respectively, such powerful tracking method as non-linear Multiple Hypothesis Tracking is thoroughly discussed. Also, the *Theory of Unified Tracking* approaches is presented as a promising instrument for successful development of multiple target tracking algorithms in cases of critical uncertainty.

The book contains many illustrative examples, concept descriptions, and specific algorithms. Cases with nonlinear target behavior models, non-Gaussian measurement error distributions, low scanning rates, low signal to noise ratios and multiple closely spaced targets are under special consideration. The authors treat a number of topics such as the problem of multiple target detection and tracking; the case for the

Bayesian inference; single target tracking; Bayesian filtering; Kalman filtering; discrete Bayesian filtering; classical multiple target tracking; general multiple hypothesis tracking; classical multiple hypothesis tracking; multiple target tracking without contacts or association; general multiple target model; relationship to multiple hypothesis tracking; the theoretical foundations for likelihood ratio detection and tracking; as well as implementation issues.

The book might be of significant interest for students, specialists and professionals working in field of reliable situation and threat assessment on the base of effective multisensor data fusion. It will be especially useful for people searching effective procedure for crisis, conflict and collision avoidance, conflicts prevention and crisis management on the base of reliable data processing. The approach offered in the book for dynamic objects state estimation and prediction in case of significant volatility, uncertainty, complexity and ambiguity is an effective instrument for solving real world problems.

MULTITARGET/MULTISENSOR TRACKING:
APPLICATIONS AND ADVANCES - VOLUME III

Yaakov Bar-Shalom and William Dale Blair
Artech House Radar Library, Approx. 460 pages, Available in July 2000

The book is a significant addition to previous fundamental authors' works in the area of Multisensor Multitarget Tracking. It provides the most up-to-date available information and guidance to development of new practical and effective solutions for sensor data processing systems. For people searching for innovative solutions it discusses the most important contemporary problems of advanced target tracking applications, giving the reader a chance to be in touch with the forefront of this professional area.

In particular, the book presents the modern viewpoint on multisensor tracking problems, on the allocation of insufficient resources, and on advanced hardware and software development. A thorough consideration of assignment techniques for multitarget data association is presented. It includes the incorporation of the Nearest Neighbor Joint Probabilistic Data Association algorithm into the Interacting Multiple Model estimator. It also considers non-linear filtering for fusing target's kinematic state measurements and target's signature measurements. A Variable Structure Interacting Multiple Model (VS-IMM) estimator combined with an Assignment algorithm for tracking multiple ground targets is thoroughly discussed. The effective use of MTI data obtained from an airborne sensor is studied and the obtained results could be of great interest for professionals involved in radar data processing.

The book includes an in-depth discussion of techniques, related to corrupted radar tracking performance. It presents ways of modeling and simulating ECMs, using computers. A detailed signal processing model is proposed to help sonar/radar waveform optimization for reliable tracking. A comprehensive introduction to variable structure estimators is provided and an accession of their practical applications is made.

The book covers practical aspects of multisensor tracking and sensor resource allocation; survey of assignment techniques for MTT; IMM estimator with nearest neighbor; joint probabilistic data association; tracking; closely-spaced, deformable objects; tracking for Ballistic Missile Defence; joint target tracking and identification: an application of nonlinear filtering; ground target tracking with topography-based variable structure IMM Estimator; radar signal processing for tracking; optical sensor signal processing for tracking; modeling of electronic countermeasures for multitarget tracking and data association; sonar/radar waveform design for optimal tracking performance; engineer's guide to variable structure estimators for tracking.

The book will be of great interest for designers and systems engineers, involved in sensor data processing for wide area of application. It could be especially useful for professionals, engaged in R&D of multisensor data fusion algorithm for conflict prevention, collision avoidance and crisis management in air, ground and sea applications. Also, it could be of interest for specialists applying dynamic objects state estimation in variety of public safety ensuring systems.

SENSORS FOR PEACE

APPLICATIONS, SYSTEMS AND LEGAL REQUIREMENTS FOR MONITORING IN PEACE OPERATIONS

Editors: Jurgen Altmann, Horst Fisher and Henny van der Graaf
United Nations Publication, New York, 1998, ISBN 92-9045-130-0

The book is devoted to one of the vital problems of peace operations: monitoring of situations and threats in unstable, uncertain, complicated and deceptive environments. The main goal of the authors is to analyze the use of unattended ground sensor systems in four important areas of application, and to provide recommendations on the employment of sensors in peace operations. The importance of this publication is unquestionable. There is no clearer example of practical effectiveness of the system of multiple sensor utilization and its potential contribution to increasing international security. But in our point of view, the most valuable contribution of this publication are lessons learned in the sensor system utilization during difficult times of particular peace operations.

The presentation begins with thorough consideration of operational aspects of the use of sensors in peace operations. It clearly shows how sensors fit into different tasks carried out by peace forces, and how sensor systems and personnel requirements interact. Special attention is paid to the use of sensors under various circumstances, i.e., in mobile tasks such as patrolling. Very useful is the presentation of operational requirements cost estimation and organizational set-up. Using many tables with technical characteristics and rich illustrations, the authors introduce the reader into the essence of the sensor systems information fusion and the specifics of their application.

An important evaluation of the Questionnaire on Application of Ground Sensors during peacekeeping Operations is presented next. The study covers up-to-date technology capability utilization, systems optimization, and efficiency improvement. It describes capabilities provided by systems already available on the market. The cost of such systems and their development are specified in detail.

The legal aspects of ground sensor utilization in peace operations are discussed at the end of the book. International law aspects are carefully investigated and the need for new rules in regulating the sensor systems implementation is confirmed.

Finally, a set of important conclusions and recommendations are formulated. Options for decision-makers and policy recommendations for United Nations, as well as for contributing states are given. Thus, the book may be regarded as an important study, which establishes close connections between multisensor data fusion and security issue. It will be useful for specialists, working in the area of multisensor data fusion engineering applications.

INFORMATION FUSION TERMINOLOGY

Information Fusion encompasses theory, techniques and tools conceived and employed for exploiting the synergy in information acquired from multiple sources (sensor, databases, information gathered by human, etc.). The objective is that the resulting decision or action is in some sense better (qualitatively or quantitatively, in terms of accuracy, robustness etc.) than it would be possible if any of these sources were used individually, i.e., without exploiting synergy.

In the process of fusion events, activities and movements are correlated and analyzed as they occur in time and space. The purpose is to determine location, identity and status of individual objects (equipment and units), to assess the situation, to determine qualitative and quantitative characteristics of threats to coalition operations, and to detect patterns in activities that reveal intent or capability. Specific technologies are required to refine, direct and manage the information fusion capabilities.

In relation to Multisensor Data Fusion, Multi-Sensor Collaboration is performed as an innovative technical approach, which is engaged to eliminate limitations in the current capabilities of sensors. Sensor collaboration technology must address ground, airborne and spaceborne systems and processes in a fully distributed environment. A special goal is the development of a predictive intelligence assessment of the warfighter's battlespace situation.

Data Fusion is a process dealing with the association, correlation, and combination of data and information from single and multiple sources to achieve refined position and identity estimates, complete and timely assessment of situations and threats, as well as their significance.

Often, data fusion is accompanied by sensor management. A sensor management system is any system which provides automatic control of a suite of sensors or measurement devices. In general, a sensor management system must answer the following four questions: 1) What sensor? 2) Which service? 3) Where to point? 4) When to start? The sensor manager output is a schedule defined over an interval of time where each entry of the schedule is a scheduling vector containing the answers to these questions.

In practice, Data Fusion is a formal framework in which are expressed means and tools for the alliance of data originating from different sources, and for the exploitation of their synergy in order to obtain information whose quality cannot be achieved otherwise. More philosophically (B. Dasarathy, Dynetics, Inc.) - "When you borrow information from one source, it’s plagiarism; When you borrow information from many, it’s information fusion"

Concerning multisensor fusion, the general problem can be restated as: how is it possible to observe a dynamical scene with a set of sensors by controlling their configuration, i.e. their sequencing, as well as the scheduling of the resources, be they directly attached to the sensors or centralized. Evaluating the reliability of different information sources is crucial when the received data reveals some inconsistencies and we have to choose among various options. In fact, the reliability of the source affects the credibility of the information and vice-versa. It is necessary to develop systems that deal with couples (information, source) rather than with information alone.

Decentralized distributed detection and decision fusion systems attract significant interest due to the increasing need to employ multiple sensors for surveillance, intelligence and communications. Some of the motivating factors are the natural advantages of distributed detection over centralized detection: reliability, survivability, increases in required coverage of surveillance, and reduction in communications bandwidth.

One purpose of Sensor Fusion is to realize new sensing architecture by integrating multi-sensor information and to develop hierarchical and decentralized architecture for recognition such as human beings further. As a result, more reliable and multilateral information can be extracted, which can realize high-level recognition mechanism.

INTRODUCTORY LITERATURE:

D.S. Lawrence, D. Stone, et.al., Bayesian Multiple Target Tracking, (Artech House Radar Library, 1999).

A. Zembower, "Emerging Trends in Sensor Data Management," in Proceedings of the 15th Annual AESS/IEEE Dayton Section Symposium Sensing the world: Analog Sensors and Systems Across the Spectrum (May 1998), 71-78.

M.S. Markin, et.al., *Data Fusion and Data Processing* (The Report of the Defence and Aerospace Foresight Working Party, 1997).

K. Varshney, Distributed Detection and Data Fusion (Springer 1996).

J. Manyika and H. Durrant-Whyte, Data Fusion and Sensor Management: A decentralized information theoretic approach (Ellis Horwood, 1994).

D.L. Hall, Mathematical Techniques in Multisensor Data Fusion (Artech House, 1992).

M.A. Abidi and R. C. Gonzalez, Data Fusion in Robotics & Machine Intelligence (Academic Press, 1992).

J.J. Clark and A.L. Yuille, Data Fusion for Sensory Information Processing Systems (Kluwer Academic Publishers, 1990).

E. Waltz and J. Llinas, Multisensor Data Fusion (Artech House, 1990).

INTERNET ADDRESSES FOR REFERENCES:

http://www-datafusion.cma.fr/fund/definitions.html

http://www.inform.unian.it/area/cognitive/Fusion.htm

http://dflwww.ece.drexel.edu/research/dds

http://roadway.ivhs.washington.edu/pubs/fusion_abstract.htm

INTERNATIONAL SOCIETY OF INFORMATION FUSION EVENTS:

SPIE's International Symposium on AeroSense - Signal Processing, Sensor Fusion and Target Recognition IX, Orlando, FL, USA.

Threats, Countermeasures, and Situational Awareness: Teaming for Survivability - Symposium and Exhibition, Virginia Beach, June 20-22, 2000.

Fusion2000 - Third International Conference on Information Fusion, Paris, France, July 10-13, 2000.

Fusion of Soft Computing & Hard Computing in Industrial Applications, Session at SMC2000, October 8-11, 2000, Nashville, TN, USA.

CENTRAL LABORATORY FOR PARALLEL PROCESSING

The Central Laboratory for Parallel Processing (CLPP) was established in 1985 as a Coordination Center of Informatics and Computer Technology (CCICT). The main idea was to coordinate research in the field of Computer Science and Computer Technologies conducted by scientists from the Bulgarian Academy of Sciences, Bulgarian universities and R&D institutes closely connected with industry, as well as to promote international cooperation in the area of theoretical and practical problems of the new generation of computers. Special emphasis was placed on the following issues:

- high performance computer systems and algorithms for parallel processing
- distributed computer systems
- computer networks
- intelligent man-machine interface, etc.

Annually, the scientists from the Laboratory publish approximately 140 papers, and about hundred of them are published in refereed international journals and proceedings of high quality international conferences. In 1996, CCICT was renamed as Central Laboratory for Parallel Processing. CLPP is headed by a Director, a Deputy Director and a Scientific Secretary. Currently, Prof. D.Sc. Ivan Dimov is Director of CLPP. General and scientific policy of the Laboratory is formulated by Board of Directors, including all Department heads, and the 24-member Scientific Council. Currently, the CLPP consists of a Computer Center and six departments:

- Distributed computing systems and networks
- Parallel algorithms
- Scientific computing
- High performance computer architectures
- Linguistic modeling
- Mathematical methods for sensor information processing.

The **Department of Distributed Systems and Networking** was founded in 1985. It is chaired by Prof. Dr. K. Boyanov, Corresponding member of the Academy of Sciences. Main areas of research within the department are:

- Network Protocols
- Parallel and Distributed Heterogeneous Computing Environments
- High Speed Local Area Networks
- Data Messaging
- Broadband communications
- Parallel interpretation of object-oriented programs
- Dynamic load balancing in distributed systems

A concept of distributed computer architecture with reconfigurable communications interconnection was developed. Based on this architecture several high performance computers with modular structure and up to 64 processors were constructed. Architecture allowing flexible use of high-speed networks has been suggested. The department is coordinator of the Bulgarian Academic Network. The studies accomplished in the Department are aimed at the creation of a methodology for effective parallel interpretation of wide range of applications which would merge the advantages of parallel processing and the specification of user applications by means of graphical (diagrammatic) high level object-oriented language. Currently, the Department of Distributed Systems and Networking participates in several international joint research programs such as ACTS, NATO Science for Peace, as well as in bilateral reasearch projects on parallel algorithms. Its staff consists of one corresponding member, two full professors, three associate professors, eight research fellows, and four support specialists.

The main research activities of the **Department of Parallel Algorithms** are in the following areas:

- New efficient parallel algorithms;
- Monte Carlo algorithms (differential and integral equations, linear algebra, spectral problems, data processing);
- Fractal methods for image processing;
- Computational geometry and topological graph theory;
- Applications of parallel algorithms and supercomputing (large-scale problems, parallel and/or vector computers, clusters of workstations).

The Department of Parallel Algorithms participates in several international joint research programs financed by the Commission of the European Communities, NATO Science for Peace and other sources.

The Department organizes a number of international scientific meetings - conferences, workshops and seminars. The traditional IMACS Seminar on Monte Carlo methods is jointly organized by IMACS and the Central Laboratory for Parallel Processing.

The Department of Parallel Algorithms employs one academician, one full professor, four associate professors, six scientific researchers, and one supporting specialist.

The **Department of Scientific Computing** was founded in 1997. The major objectives of the research activities of the Department are as follows:

(i) to develop new efficient numerical methods which are robust with respect to the problem and method parameters, and which can also perform efficiently on modern computer systems, including parallel ones;

(ii) to implement the developed algorithms and to create software tools, as well as to test them on benchmark problems close to the advanced requirements of real-life computer simulation practice.

Currently the Department of Scientific Computing participates in several international joint research programs financed by EU, NSF-USA, Volkswagen, etc. The successfully finalized in 1998 Copernicus Project "High Performance Computing in Geosciences. Safety of Constructions with Respect to Rock Deformations and Movements" represents the abilities of the group from the Department of Scientific Computing to perform high level research in an interdisciplinary international research team.

The Department organizes the biannual Workshop on "Large-Scale Scientific Computations".

The Department of Scientific Computing numbers two associated professors, two senior research fellows and one supporting researcher.

The **High Performance Computer Architecture (HPCA) Department** at the Central Laboratory for Parallel Processing was founded in 1998 at the Bulgarian Academy of Sciences and is chaired by Prof. Vladimir Lazarov who led High Performance Systems and Parallel Algorithms Laboratory existing since 1986. The research and development areas cover:

- Computational Models;
- Advanced Computer Architectures;

- Computer Simulation of HPCA.

The department staff consists of eight researchers: three associate professors and five senior researchers.

The **Department of Linguistic Modeling** was set up in 1987 as Linguistic Modeling Laboratory. The formation of the Laboratory was intended to meet the modern trends in the research and application of natural language processing. The Department's main tasks are:

- Computer modeling of basic fragments of the Bulgarian language - lexical and grammatical resources. A computer dictionary of Bulgarian (70 000 units) was prepared in two versions.
- Computer modeling of Slavonic languages. (Computer dictionary of Russian - 100 000 units).
- Computer processing of multilingual resources (Bilingual aligned Corpora base is compiled for French-English, French-Bulgarian and English-Bulgarian parallel texts: 2.5 Million words).
- Methods and tools for knowledge based machine aided translation (System for machine-aided human translation with generation of explanations in natural language).

The Department of Linguistic Modeling have actively participated in twelve international projects.

The personnel of the Department of Linguistic Modeling enlists nine researchers, two of them being associate professors and five research fellows.

The **Mathematical Methods for Sensor Data Processing Department** (MMSDP) at the Central Laboratory for Parallel Processing (CLPP) is founded in 1988 at the Bulgarian Academy of Sciences.

It specializes in solving complex theoretical and practical problems involving sensor data processing for Bulgarian Ministry of Education and Science, Ministry of Industry, Ministry of Defense, Air Traffic Control Authorities, and Sofia Technical University.

Employing modern mathematical approaches and high performance computers, the researchers in the Department provide R&D products for solving basic problems of sensor data processing systems: automation, performance improvement, initial operator education and training. The efforts of the research team are directed both to new applications and to technological upgrade of existing sensor data processing systems. Significant experience in developing and applying effective sensor data processing approaches and methods for real-time multisource kinematic and attribute data correlation, association, estimation and fusion is accumulated. The main R&D areas cover the following directions of real-time sensor data processing:

- Multiple Sensor Multiple Target Tracking (track initiation, measurements data association, measurements and tracks fusion)
- Stochastic systems identification and hybrid estimation
- Automated collision warning/avoidance in navigation conflicts (object’s optimal control)
- Parallel MTT algorithm design and implementation.

In 1999, the department consists of 13 researchers: two full professors, two associate professors and seven senior researchers. Two of them have D.Sc. degrees and nine have Ph.D. degrees.

More information on Central Laboratory for Parallel Processing is available at its Web site: **http://www.acad.bg/**