

Preface

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. Appropriate collection, registration, and alignment, stochastic filtering, logical analysis, space-time integration, exploitation of redundancies, quantitative evaluation, and appropriate display are part of Sensor Data Fusion as well as the integration of related context information. The technical term “Sensor Data Fusion” was created in George Orwell’s very year 1984 in the US defence domain, but the applications and scientific topics in this area have much deeper roots. Today, Sensor Data Fusion is evolving at a rapid pace and present in countless everyday systems and civilian products.

Although a vast research literature with specialized journals and conference proceedings, several handbooks, and scientific monographs deal with Sensor Data Fusion, it often seems difficult to find access to the underlying general methodology and to apply the inventory of various fusion techniques to solving individual application problems. To facilitate the transfer of notions and algorithms of Sensor Data Fusion to problem solving in engineering and information systems design is the main objective of this book. The idea of it has grown from both the author’s lecturing on Sensor Data Fusion at Bonn University since 2002 and extensive research work at Fraunhofer FKIE on improving defence- and security-related surveillance and reconnaissance systems by Sensor Data Fusion. The inner structure of the book directly follows from these considerations.

Sensor Data Fusion, as an information technology as well as a branch of engineering science and informatics, is discussed in an introductory chapter, put into a more general context, and related to information systems. Basic elements and concepts are introduced.

Part I presents a coherent methodological framework of Sensor Data Fusion, thus providing the prerequisites for discussing selected applications in Part II of the book in four chapters. The presentation reflects the author’s views on the subject and emphasizes his own contributions to the development of particular aspects.

Based on a more general notion of object states, probabilistic models of their temporal evolution and the underlying sensors are discussed. Their proper combination within a Bayesian framework provides iterative update formulae for probability densities that represent the knowledge about objects of interest extracted from imperfect sensor observations and context information. Various data fusion algorithms appear as limiting cases and illustrate the more general Bayesian approach. Particular emphasis is placed on fusing data produced at different instants of times, i.e., on-time series of sensor data. The resulting multiple sensor tracking problem is a key issue in Sensor Data Fusion. A discussion of track initiation and fusion of locally preprocessed information, i.e., track-to-track fusion, concludes Part I.

Progress in fusion research is based on precise and methodical work on relevant, well-posed, but sufficiently specialized research questions. Besides answering them appropriately and evaluating the result in comparison to alternatives, the identification of such questions in itself is an essential part of scientific work and often far from trivial.

Following this observation, selected applications are discussed in Part II, where specific problems of Sensor Data Fusion are highlighted. Their solutions are based on the methods previously introduced, which are crucial for meeting challenging user requirements. At the same time, the application examples illustrate the inner structure and practical use of the underlying Bayesian formalism. The very success of Bayesian Sensor Data Fusion may serve as retrospective justification of the approach as well as a motivation to apply this formalism to an even broader field of applications.

The discussed examples are chosen from the author's own contributions to this area and are grouped around the following over-all topics:

1. *Integration of Advanced Sensor Properties*
2. *Integration of Advanced Object Properties*
3. *Integration of Topographical Information*
4. *Feedback to Acquisition: Sensor Management,*

which define the four chapters of Part II. The material discussed in the individual sections of these chapters is collected from journal publications and a handbook chapter by the author. Although the presentation of the key points with respect to specialized methodology and application aspects is self-contained on the methodological basis provided by Part I, a related publication of the author is displayed in each section, where more details and numerical results can be found.

The results of Part II are input for large ISR Systems (Intelligence, Surveillance, and Reconnaissance). Since the examples have been selected from sufficiently different, but mutually complementary areas in Sensor Data Fusion, the detailed analysis of the specialized problems involved and their individual solutions provide a fairly comprehensive overview of various aspects of Sensor Data Fusion for situation picture production. This type of "example-driven" discussion is perhaps better suited to stimulate research work and progress on analogous

problems in different applications than a more abstract and generalizing presentation might do.

With some delay, Sensor Data Fusion is likely to develop along lines similar to the evolution of another modern key technology whose origin is rooted 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.

This text book would not have been possible without two eminent scientists, who greatly formed the author's mind and apprehension over many years. Günther van Keuk, his teacher in tracking and Sensor Data Fusion and former department head, who died far too early in 2003, introduced him into the exciting field of Sensor Data Fusion and shaped his scientific habit. Jürgen Grosche generously accompanied the author's research as a Fraunhofer director with personal interest, valuable advice, and clear directions. In particular, Jürgen Grosche mediated the author's lecturing activities on Sensor Data Fusion at Bonn University and encouraged him to summarize his research results in this book.

Of course, the merits of many scientific colleagues should also be mentioned here, who contributed greatly through countless scientific discussions and joint work over the years, especially Klaus Becker, Richard Klemm, Martin Ulmke, and Ulrich Nickel. Furthermore, the author is indebted to Jane Stannus and Diana Dorau for their help in editorial and layout issues.

Since the inner strength for his professional life is given to the author by his family, his beloved wife Dorothea and his children Maria, Veronika, Theresia, Katharina, and Johannes, as well as by his parents and brothers, it might be appropriate to express his deep gratitude to them here as well.

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Reference

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Methodological Framework and Selected Applications

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