Preface

This book brings together two topics which themselves are complex and multi-disciplinary: the concepts of "Information Fusion" and "Context" both of which have long histories of research and development. In this Preface, we offer our perspectives on the motivations and rationales for the development of this text, and then provide our thoughts that have led to the particular organizational framework of the book.

History

The concept of ***information fusion*** can be said to have begun with the writings of Aristotle which acknowledged the integration of the human senses. With the advent of technology, the nature of sensing evolved into an understanding that data were being collected not only by the human (e.g. receptors in the retina) but also derived from physical sensors (e.g. pixels). ***Context***, as for information fusion, has its own origins in philosophy. From the early Greeks, there were various debates about the interaction of the human on, within, and outside the world. The mental perceptions and physical senses were a means to integrate the mind–body based perspectives in processes that are similar to those for contextual understanding.

The Role of Context

Three demarcations of context-enhanced information fusion include the contextually influenced functions of perception, information systems, and computing. One of the key issues associated with context is ***ecological perception*** as defined by Gibson. During the 1950s, there was the notion that the human consciousness constructs perceptions strictly from the senses; however, Gibson challenged this

notion by noting that the mind can directly interpret stimuli from the world in his 1966 work *The Senses Considered as Perceptual Systems*. Additional work included assertions that the world affords actions and ecological perception in which the notion of own-self to the world, i.e. contextual framing, conditions perception; these works constituted a milestone regarding the role of context in perception. In the 1990s, a second milestone included the large-scale physical collections of information from the world from various sensing data including weather, terrain, and roads which has become known as the ***Geographical Information System*** (GIS). From the large amounts of data being collected, researchers in information began to use this information to improve estimation accuracy. Recently, the methods of ***Context-aware computing*** demonstrate that global information can be used to modify or augment local estimation processes regarding parameters or states of interest. With the Internet, there are many possibilities enabling distributed processing, cloud-based access to information, and cognitive autonomy. Today, that information is widely available from databases, wireless connections, and cloud technology. Being able to access relevant GIS data and a broad range of other types of data has popularized the ability to use contextual information for an extensive range of applications.

Table 1 brings together these general themes of information community-established milestones. Looking at the general contributions which are rooted in the historical thoughts of the time, there are three developments of concepts and philosophy, mathematics and data integration theory, and architectures and applications. These three areas facilitated the editors' organization of the material of this book submitted from the top scientists, researchers, practitioners, and leaders in information fusion.

Table 1 Context exploitation capability evolution over time

Information perspective	Time period			
	Ancient times	1960s	1990s	2010+
Fusion	Sensing	Estimation	Multi-sensor	Information
Context	Mind–body	Ecological	GIS	Aware computing
Contextual fusion	Philosophy	Theory	Applications	Architectures

Modern Information System Applications

Modern information fusion systems must consider the specific characteristics of the application domain in which they have to operate, showing robust, and context-sensitive behaviour. Likewise, a system designer must take into consideration different sources of contextual knowledge in addition to immediate sensory data in order to develop an effective, efficient, and useful approach to situation

assessment. For applications in a wide variety of domains, contextual knowledge may include structural models of the scene, known a priori relationships between the entities and the surrounding environment, dynamic scenarios necessary to interpret or constrain the system output, and user preferences, social norms, and cultures when estimating the situations of interest for the domain. Context includes conditions which augment otherwise bounded estimates, and results in estimates of enhanced meaning. This book provides a broad framework of discussion for system designers on the use of contextual information for fusion-based estimation that, to our understanding, has not as yet been offered in the literature.

The development of information fusion (IF) systems, to include data-, sensor-, and feature-level fusion, is a necessary engineering process in diverse applications, and new domains require an increasing degree of contextualized solutions and situation–adaptation mechanisms. The potential development of IF systems inclusive of contextual factors and information offers an opportunity to improve the quality of the fused output, provide solutions adapted to the application requirements, and enhance tailored responses to user queries. Contextual-based strategy challenges include selecting the appropriate representations, exploitations, and instantiations. Context could be represented as knowledge-bases, ontologies, and geographical maps, etc. and would form a powerful tool to favour adaptability and system performance. Example applications include context-aided tracking and classification, situational reasoning, ontology building, and decision updating. Contemporary discussions of context are domain and sensor specific for which information fusion enhances performance. For example, context-aided target tracking seeks to determine kinematic movements with domain-constrained sensitivities (e.g. roads), whereas context-aided information fusion solutions utilize not only the road information, but also the social norms of the same geographical information (e.g. traffic rules).

Book Tenets

This book presents the foundational reasoning, theories, and methods for including contextual influences in fusion process design and implementation, along with the most recent results in exploiting contextual information for real-world modern applications. A balance between high- and low-level information fusion problems is highlighted to showcase performance improvements in highly demanding conditions. Holistic approaches integrating research results in different communities, which are relevant for readers outside the information fusion community, have been selected, emphasizing the need to combine different techniques to overcome limitations of a single perspective, legacy computing, or programs traditionally applied to domain-specific data and information fusion problems. Recent advances in information fusion include context exploitation, multi-level fusion performance, and hard/soft fusion. Finally, a selection of representative application domains requiring the injection of contextual knowledge is presented in the book (e.g. vision

systems, harbour surveillance, robotics, and ambient intelligence) to illustrate the process, where sensor-based data and contextual information synergistically yield more robust and informative results.

Book Outline

The book comprises six areas for which we have explored and developed relevant contributions: foundations, concepts, systems philosophy, mathematical theory, hard-soft fusion, and applications:

Fundamentals introduces the necessary terminology and key elements in information fusion and context. The main concepts are conveyed with the support of the JDL/DFIG data fusion model, helping the reader to frame context-enhanced fusion in a well-known setting.
Concepts of Context for Fusion presents central themes and issues for context-aware information fusion. A formalization of context is presented along with topics derived from context-enhanced target tracking, decision support, and threat assessment.
Systems Philosophy of Contextual Fusion discusses design issues and challenges in developing context-aware fusion systems. Several architectures are proposed where a pivotal role is given to a middleware layer dedicated to context access and discovery.
Mathematical Characterization of Context provides mathematical grounds for modelling the contextual influences in representative fusion problems such as sensor quality assessment, target tracking, and text analysis.
Context in Hard/Soft Fusion deals with the fusion of device-generated data (hard) with human-generated data (soft). Context brings together hard and soft data as an emerging topic.
Applications of Context Approaches to Fusion offers an array of applications where the exploitation of contextual information in the fusion process boosts system performance. Application domains include maritime and ground target tracking, surveillance, robotics, and assisted driving.

We hope that the information presented can be useful to various practitioners, researchers, readers, and academics pursuing applications to real-world problems where information fusion offers a solution. We have brought together the leading experts in the field to showcase their techniques of using context to enhance information fusion results.

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