Preface

This book emanated from many discussions about collaborative research among the editors. The discussions have focussed on using signal processing methods for knowledge extraction and information fusion in a number of applications from telecommunications to renewable energy and biomedical engineering. They have led to several successful collaborative efforts in organizing special sessions for international conferences and special issues of international journals. With the growing interest from researchers in different disciplines and encouragement from Springer editors Alex Greene and Katie Stanne, we were spurred to produce this book.

Knowledge extraction and information fusion have long been studied in various areas of computer science and engineering, and the number of applications for this class of techniques has been steadily growing. Features and other parameters that describe a process under consideration may be extracted directly from the data, and so it is natural to ask whether we can exploit digital signal processing (DSP) techniques for this purpose. Problems where noise, uncertainty, and complexity play major roles are naturally matched to DSP. This synergy of knowledge extraction and DSP is still under-explored, but has tremendous potential. It is the underlying theme of this book, which brings together the latest research in DSP-based knowledge extraction and information fusion, and proposes new directions for future research and applications. It is fitting, then, that this book touches on globally important applications, including sustainability (renewable energy), health care (understanding and interpreting biomedical signals) and communications (extraction and fusing of information from sensor networks).

The use of signal processing in data and sensor fusion is a rapidly growing research area, and we believe it will benefit from a work such as this, in which both background material and novel applications are presented. Some of the chapters come from extended papers originally presented at the special sessions in ICANN 2005 and KES 2006. We also asked active researchers in signal processing with specializations in machine learning and multimodal signal processing to make contributions to augment the scope of the book.

This book is divided in four parts with four chapters each.

Collaborative Signal Processing Algorithms

Chapter 1 by Jelfs et al. addresses hybrid adaptive filtering for signal modality characterization of real-world processes. This is achieved within a collaborative signal processing framework which quantifies in real-time, the presence of linearity and nonlinearity within a signal, with applications to the analysis of EEG data. This approach is then extended to the complex domain and the degree of nonlinearity in real-world wind measurements is assessed.

In Chap. 2, Hirata et al. extend the wind modelling approaches to address the control of wind farms. They provide an analysis of the wind features which are most relevant to the local forecasting of the wind profile. These are used as prior knowledge to enhance the forecasting model, which is then applied to the yaw control of a wind turbine.

A collaborative signal processing framework by means of hierarchical adaptive filters for the detection of sparseness in a system identification setting is presented in Chap. 3, by Boukis and Constantinides. This is supported by a thorough analysis with an emphasis on unbiasedness. It is shown that the unbiased solution corresponds to existence of a sparse sub-channel, and applications of this property are highlighted.

Chapter 4 by Zhang and Chambers addresses the estimation of the reverberation time, a difficult and important problem in room acoustics. This is achieved by blind source separation and adaptive noise cancellation, which in combination with the maximum likelihood principle yields excellent results in a simulated high noise environment. Applications and further developments of this strategy are discussed.

Signal Processing for Source Localization

Kuh and Zhu address the problem of sensor network localization in Chap. 5. Kernel methods are used to store signal strength information, and complex least squares kernel regression methods are employed to train the parameters for the support vector machine (SVM). The SVM is then used to estimate locations of sensors, and to track positions of mobile sensors. The chapter concludes by discussing distributed kernel regression methods to perform localization while saving on communication and energy costs.

Chapter 6, by Lenz et al., considers adaptive localization in wireless networks. They introduce an adaptive approach for simultaneous localization and learning based on theoretical propagation models and self-organizing maps, to demonstrate that it is possible to realize a self-calibrating positioning system with high accuracies. Results on real-world DECT and WLAN groups support the approach.

In Chap. 7, Host-Madsen et al. address signal processing methods for Doppler radar heart rate monitoring. This provides unobtrusive and ubiquitous detection of heart and respiration activity from distance. By leveraging recent advances in signal processing and wireless communication technologies, the authors explore robust radar monitoring techniques through MIMO signal processing. The applications of this method include health monitoring and surveillance.

Obradovic et al. present the fusion of onboard sensors and GPS for real-world car navigation in Chap. 8. The system is based on the position estimate obtained by Kalman filtering and GPS, and is aided by corrections provided by candidate trajectories on a digital map. In addition, fuzzy logic is applied to enhance guidance. This system is in operation in a number of car manufacturers.

Information Fusion in Imaging

In Chap. 9, Chumerin and Van Hulle consider the detection of independently moving objects as a component of the obstacle detection problem. They show that the fusion of information obtained from multiple heterogeneous sensors has the potential to outperform the vision-only description of driving scenes. In addition, the authors provide a high-level sensor fusion model for detection, classification, and tracking in this context.

Aghajan, Wu, and Kleihorst address distributed vision networks for human pose analysis in Chap. 10. This is achieved by collaborative processing and data fusion mechanisms, and under a low bandwidth communication constraint. The authors employ a 3D human body model as the convergence point of the spatiotemporal and feature fusion. This model also allows the cameras to interact and helps the evaluation of the relative values of the derived features.

The application of information fusion in E-cosmetics is addressed by Tsumura et al. in Chap. 11. The authors develop a practical skin color analysis and synthesis (fusion) technique which builds upon both the physical background and physiological understanding. The appearance of the reproduced skin features is analysed with respect to a number of practical constraints, including the imaging devices, illuminants, and environments.

Calhoun and Adalı consider the fusion of brain imaging data in Chap. 12. They utilize multiple image types to take advantage of the cross information. Unlike the standard approaches, where cross information is not taken into account, this approach is capable of detecting changes in functional magnetic resonance imaging (fMRI) activation maps. The benefits of the information fusion strategy are illustrated by real-world examples from neurophysiology.

Knowledge Extraction in Brain Science

Chapter 13, by Mandic et al. considers the "data fusion via fission" approach realized by empirical mode decomposition (EMD). Extension to the complex

domain also helps to extract knowledge from processes which are strongly dependent on synchronization and phase alignment. Applications in real-world brain computer interfaces, e.g., in brain prosthetics and EEG artifact removal, illustrate the usefulness of this approach.

In Chap. 14, Rutkowski et al. consider some perceptual aspects of the fusion of information from multichannel EEG recordings. Time–frequency EMD features, together with the use of music theory, allow for a convenient and unique audio feedback in brain computer and brain machine (BCI/BMI) interfaces. This helps to ease the understanding of the notoriously difficult to analyse EEG data.

Cao and Chen consider the usefulness of knowledge extraction in brain death monitoring applications in Chap. 15. They combine robust principal factor analysis with independent component analysis to evaluate the statistical significance of the differences in EEG responses between quasi-brain-death and coma patients. The knowledge extraction principles here help to make a binary decision on the state of the consciousness of the patients.

Chapter 16, by Golz and Sommer, addresses a multimodal approach to the detection of extreme fatigue in car drivers. The signal processing framework is based on the fusion of linear (power spectrum) and nonlinear (delay vector variance) features, and knowledge extraction is performed via automatic input variable relevance detection. The analysis is supported by results from comprehensive experiments with a range of subjects.

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