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Editorial

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The sensor array technology has proven itself to be one of the most active research subjects in the past few decades. The initial concept, which originated from aerospace applications, now finds itself evolving in many other dimensions to a vast variety of applications. Recently, there has been a lot of interest in developing sensor networks for the military and security to monitor an area, including detecting, identifying, locating, and tracking the emission signals of interest. Similar ideas have been found in microphone and seismic arrays, where audio/seismic signals can be enhanced under noisy conditions and objects may be tracked with the directional capability the sensor array provides. The recent US FCC E911 requirement to locate the mobile phone users upon emergency has also brought a new wave of interests in the subject within the communications community. The research in smart antennas to combat multipath fading, provide interference suppression, and enhance capacity for communication systems has also been a very popular subject. In the aerospace community, recent focus has been on space-time adaptive processing (STAP) techniques to provide state-of-the-art moving target detection in the presence of jamming and clutter and high-resolution radar imaging.

Over the years, the classical array signal processing methods have been modified toward different types of sensors with different classes of algorithms adapting to different signals and media of propagation. Many seek to provide robust performance in practical environments or exploit new properties of a specific problem, and others seek to provide efficient solutions with minimum implementation costs. In the current issue, we collect a sample of the recent active research work in the area of sensor array. The current issue features 10 high-quality papers on the advances of sensor array technology. Since the research in sensor array technology covers a wide range of topics, we have organized the chosen papers in the areas of signal detection and number of sources determination, time delay estimation, direction of arrival and source localization, and STAP techniques.

Signal detection and number of sources determination

Signal detection is an essential part of a sensor array system. The detector is responsible for initiating the estimator once a desired signal is detected as present. The signal detector needs to be accurate and fast at the same time to be effective. In many applications of sensor array, there may be multiple desired signals of interest. Then, the detection problem becomes a determination of the number of sources present. A correct determination of the number of sources is as important as determining the whereabouts of the sources; therefore, this topic has been well studied in the literature in the theoretical settings. Recent focus of the topic has been on applying the methodologies in more practical settings. The first two papers of this issue seek to provide new methods to improve the performance and speed over the existing methods.

The first paper by E. Fishler et al. addresses the problem of determining the number of sources impinging on the array for typical non-Gaussian communication signals. The proposed method is formulated by using the non-Gaussian distribution of transmitted signals in place of the Gaussian assumption in the classical minimum description length (MDL) information theoretic criterion. The resulting more accurate formulation shows improved performance and higher-resolution capacity, that is, detecting a number of sources higher than the number of array elements. Furthermore, the authors present a novel analytical tool to predict the asymptotic performances of MDL estimators. The second paper by T. Oskiper and H. V. Poor considers efficient detection of a signal impinging on the array from an unknown angle. The proposed method is an extension of the classical CUSUM algorithm to include a parallel change detection algorithm with a crude estimation of the incident angle.

The asymptotic mean detection delay and mean time between false alarms are given analytically to evaluate the effectiveness of the proposed algorithm.

Time delay estimation

Time delay estimation has been one of the earliest array signal processing topics. Many directions of arrival (DOAs) and source localization algorithms, especially in acoustic array applications, perform the estimation after the relative time delay of the impinging signal across the array is first estimated. The traditional time delay estimation methods have been extensively studied and have shown promising results in ideal environments. Recent studies have emphasized on improving the time delay estimation techniques to work in realistic environments, where reverberation exists in most indoor areas, and would cause serious degradation using conventional methods. In the paper by Jingdong Chen et al., a modified version of the average magnitude difference function (AMDF) is proposed to provide robust estimation in both reverberant and strong noise environments. The performances of the new method and the traditional methods using generalized cross-correlation (GCC) and AMDF are compared under realistic reverberant and noisy environments.

Direction of arrival and source localization

The next five papers are in the most popular area of DOA and source localization. The paper by A. J. Weiss and A. Amar considers a direct position determination method of multiple radio signals. Direct location estimation is more optimum than the common triangulation of independent source angle estimates from different sensor arrays, for example, base stations. The proposed method provides a maximum-likelihood-like estimation with only a two-dimensional search instead of the multidimensional search of the actual maximum-likelihood estimation. In the paper by P.-J. Chung et al., a recursive DOA estimation of multiple moving sources is presented. The technique uses a recursive expectation-maximization (EM) along with a linear polynomial model to improve the estimation in fast changing DOA and bearing crossing situations. The proposed technique has the advantage of efficient implementation and can easily be extended to wideband applications.

The next three papers deal with the advances of the well-known multiple signal classification (MUSIC) algorithm for the direction of arrival estimation. H. Yan and H. H. Fan present an improved cyclic MUSIC algorithm utilizing the cyclostationarity of communication signals. They show that the DOA estimation of cyclic MUSIC is biased and present a method to substantially reduce the estimation bias by properly choosing the steering vector frequency. In addition, the cyclic conjugate correlation is exploited to further improve the estimation performance. The paper by P. Chargé and Y. Wang deals with an improved root-MUSIC-like DOA estimation for cyclostationary signals. The cyclic property provides signal selectivity, thus providing suppression of interference. The estimation is low in computational cost since it only involves polynomial root finding in place of parameter searching. In the paper by S. Miron et al., the problem of polarized seismic source localization is considered. The method is based on higher-order eigendecomposition of data collected by a vector-sensor array, which is a tensorial version of the MUSIC algorithm combining DOA and signal polarization estimation.

STAP techniques

The last two papers are in the area of STAP techniques. In the paper by F. D. Lapierre and J. G. Verly, the improvement of detecting slow-moving targets using bistatic STAP radar is presented. The authors consider the nonstationarity of the covariance matrix snapshot statistics with respect to range and propose a practical registration-based range compensation using only a single realization of the stochastic snapshot at each range to improve the performance. The paper by Y. Zhang et al. deals with the subband array implementations of STAP algorithms. The steady-state performances of several subband arrays with centralized and localized feedback schemes, under different decimation rates, and for both unconstrained and constrained adaptation, are analyzed and compared.

The wide range of topics in this special issue demonstrates the applicability of the sensor array technology in various fields. We would like to thank the authors and the reviewers for contributing their time and effort to make this special issue successful. We believe the readers will benefit from the papers in this issue and find them useful references for their own work. We also hope this special issue can serve as a catalyst for further exciting research in the field of sensor array systems.

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Joe C. Chen received his Ph.D. degree in electrical engineering from the University of California, Los Angeles (UCLA), USA, in 2002. Since 1997, he has been with the Sensor and Electronic Systems Group, Raytheon Systems Company (formerly Hughes Aircraft), El Segundo, Calif, working in the field of space-time adaptive processing for airborne radar. Since 2002, he has been with Northrop Grumman Space Technology (formerly TRW), Redondo Beach, Calif, working in the field of protected communications with nulling antenna and phased array antenna for communication satellites. Dr. Chen has been the Sensor Array Special Session Organizer of IEEE Instrumentation and Measurement Technology Conference (IMTC) in 2004, and currently serves as an Associate Editor of EURASIP Journal on Applied Signal Processing. He had numerous publications in the sensor array area, particularly in the subject of wideband source localization and beamforming for acoustic signals, and he holds a US patent in the area of processing of synthetic aperture radar (SAR) images. His research interests include estimation theory and statistical signal processing as applied to sensor array systems, radar systems, and communication systems. Dr. Chen is a Member of the Tau Beta Pi and Eta Kappa Nu Honor Societies.

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