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FINAL TECHNICAL REPORT
ONR GRANT N00014-00-1-0141

H. Vincent Poor, Principal Investigator

September 26, 2003

Technical Progress

Progress under this three-year grant is summarized below, grouped roughly by fiscal year.

FY02: This year's progress included contributions to several areas. In particular, we developed blind multiuser detection algorithms for data detection in CDMA systems without the need for a priori timing information. This work, described in [1] and [5], is of significance because it allows the multiuser reception without the necessity of first acquiring the symbol timing, a problem which has not been solved satisfactorily in heavy multiuser environments. These new methods are of particular interest in packet radio networks (especially with short packets), in which timing must be reacquired on each packet. The ability to acquire timing blindly minimizes overhead, thereby saving spectrum and lowering interceptability. This also allows operation in eavesdropping mode.

In a second contribution, reported in [16] (see also [13]), we developed a general theory of signal analysis for self-similar processes based on a reproducing kernel Hilbert space (RKHS) representation of such processes. This theory is sufficiently general to produce algorithms for detection, estimation and filtering of self-similar processes, which are of widespread interest due to their occurrence in many natural and man-made phenomena (Internet traffic, phase noise, etc.).

A third contribution, described in [17], [19] and [20], has been the development and analysis of a powerful and efficient algorithm for multi-alternative change detection. This algorithm, known as the matrix CUSUM, is of widespread interest in many applications, including surveillance and security monitoring, signal detection, communications networking, etc.

We also completed and published a major review article [2] in which we describe the state of the art of interference suppression in spread-spectrum systems. This is the first major survey of this area since Milstein's 1988 survey (also published in the Proceedings of the IEEE), and covers the many powerful algorithms that have been developed in the intervening fifteen-year span.

Finally, we presented two invited papers, one [24] on statistical change detection in a DIMACS workshop on homeland defense, and the second [23] on the new concept of "turbo fusion" at FUSION2002. (This work is the basis for one of our main thrusts described in Section B.2.b.)

FY01: This year, our research activities also resulted in a number of results across a spectrum of areas in statistical signal processing.

Papers [21] and [22] describe broadly applicable techniques for interference suppression in wireless communication systems. Paper [21] particularly addresses the problem of interference suppression in spread-spectrum overlay systems. These methods are of increasing interest to the Navy due to spectrum crowding in general, and to changes in operational tactics. For example, in the deployment of littoral sonobuoy arrays with very-high-frequency (VHF) links, on-shore and near-shore commercial radio traffic represents a significant source of co-channel interference.

A further approach to non-cooperative communications and eavesdropping (beyond that discussed in [1] and [5] mentioned above) is discussed in [27], [28], and [29]. In particular, these publications consider the pure eavesdropping problem for CDMA networks, in which the receiver must determine both signature sequences and data. An approach based on the expectation-maximization (EM) algorithm is developed, and this proves to be an effective, low-complexity approach to this problem.

Paper [10] is a general review of methods for detecting stochastic processes. (This paper was developed as part of a celebration of the 50th anniversary of information theory.) This paper considers the classic methods of binary signal detection, as well as a number of more algorithmically oriented methodologies, such as sequence detection (e.g., multiuser detection, equalization, Viterbi decoding) and quickest detection.

Publications [13], [14] and [15] consider the linear modeling, analysis and processing, of self-similar stochastic processes, which as noted above are of considerable interest in the modeling of physical phenomena, economic data, and, more relevantly, IP network traffic. In this work, a powerful connection between such processes and stationary stochastic processes is exploited to develop canonical methods for signal processing and time-series analysis in the self-similar regime.

Finally, papers [25] and [26] deal with multirate signal processing and wavelet transforms over finite fields. This work is of importance in applications such as the design and decoding of multi-level error correcting codes, which are in turn of interest in wireless multimedia networks.

FY00: Many of the results of this year are captured in the above discussion and the relevant publications (typically conference publications leading to subsequent journal articles) have been cited there. Exceptions are as follows. In the area of advanced signal processing techniques for multiple-access communication, our efforts were focussed on the development of channel-estimation methods to support adaptive demodulation in CDMA networks [4], [6], [7], [30]; methods for activity detection and blind demodulation in CDMA

networks [18]; and fast beam-switching of multibeam antennas in CDMA networks [12]. Other contributions included improved methods of nonlinear filtering [9], [11].

Details of this progress can be found in our ONR-supported publications appearing since our last proposal. These are included in the following bibliography, as cited above.

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