Adaptive Set-Membership Signal Processing in Communications

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Abstract — **A novel filtering methodology, recently introduced as a viable tool for adaptive signal processing, is presented for applications to interference suppression in communication systems. This technique is based on bounding the worst-case filter error by a designer-specified value.**

I. Introduction

This paper presents some recent work on alternative methodologies for filtering based on a deterministic error specification with applications to emerging communications technologies. Most problems of interference suppression in present and future generation communication systems require the use of high performance (in terms of tracking, accuracy and robustness) and low-complexity adaptive signal processing methodologies. An attractive solution, which offers performance beyond what is possible by conventional techniques is the so-called *Set-Membership Filtering (SMF)* paradigm. These methods give rise to an admissible *set* of filters which meet a certain bounded error requirement. This formulation is an extension of the theory of Set-Membership Identification (SMI) [1] so as to handle: system identification with possibly unbounded noise, and model independent, hence general, filtering problems.

II. Interference Suppression in Communications

There are numerous problems of interference suppression/cancellation in communication systems that require sophisticated adaptive signal processing. Some of these are: *channel estimation, single user channel equalization with linear and decision feedback structures, linear multiuser detection for DS-CDMA systems, and adaptive antenna arrays for interference suppression in single and multiple user communication systems.*

Most commonly used methods rely on the availability of accurate models for the observed signals. The resulting adaptive algorithms usually suffer from an unacceptable complexity versus performance trade-off. Moreover, wireless systems require the adaptive schemes to be fast tracking and also exhibit a degree of robustness to modeling errors. It is therefore of immense practical importance to develop adaptation algorithms featuring such properties. Adaptive SMF has been shown to be a viable tool for mitigating interference in communication systems.

III. SMF and Adaptive Algorithms

The objective is to design a filter whose output error is not greater than a specified value for all possible input-desired output pairs. Assume that the input-desired output pairs, $(\mathbf{x}, d)$, come from a certain design space, $\mathcal{H}$. In SMF, the linear-in-parameters filter, denoted by θ, is to be chosen such that the error, e, satisfies $\sup_{(\mathbf{x},d)\in\mathcal{H}} |e(\theta, \mathbf{x}, d)| \leq \gamma$ for a designer-specified positive real number γ. In contrast, traditional least-squares like methodologies minimize the ensemble or time-averaged squared error. The bounded error specification in turn leads to a set of parameters satisfying the criteria if it is not too stringent. Therefore, the objective of SMF is to estimate the so-called *feasibility set*, or a member of it. The bound, γ, has to be chosen such that the feasibility set is non-empty.

Adaptive algorithms to estimate a member of this set are based on the concept of Optimal Bounding Ellipsoid (OBE) algorithms [1]. It can be shown straightforwardly that these adaptive algorithms, generically referred to as SMART (Set-Membership Adaptive Recursive Techniques), can be used to approximate the feasibility set in the context of SMF. Good convergence properties of such algorithms would imply that the ellipsoids asymptotically approach this set in some meaningfully defined sense. These adaptive SMF algorithms employ computationally simple tests for checking if an update of the parameter vector estimate is needed or not at every instant in time based on the magnitude of the prediction error. This results in data-selective and sparse updating of the parameters. It turns out that these algorithms also feature excellent estimation capability for tracking fast time varying systems. Moreover, it has been shown that the centroid of the ellipsoid can be derived as a solution of a certain constrained least-squares problem. The region estimates provided by the ellipsoid result in the algorithms being *robust* to model deviations. The selective update capability can be exploited to derive computational benefits by sharing of updators when multiple filters need to be adapted. This scheme is referred to as USHAPE (Updator SHared Adaptive Parallel Estimation). In all of the aforementioned communications examples, it has been demonstrated that the use of these SMART algorithms results in better estimation and tracking at reduced computational costs as compared to traditional methods available in adaptive signal processing.

IV. Conclusions

This paper outlined a novel field of filtering with much promise for applicability to a wide-ranging array of problems in communication systems that require high performance but low complexity adaptive signal processing methods.

References

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