Short-data-record adaptive filtering: The auxiliary-vector (AV) algorithm

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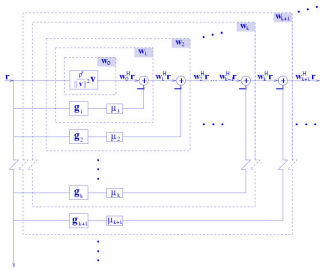
AV filters: Favorable properties

- Sequence of filters that converges to the MMSE/MVDR solution.
- Computationally simple recursions (no matrix inversion, decomposition or diagonalization).
- For short data records, the early non-asymptotic elements of the generated sequence of AV filter estimators offer favorable bias/variance balance and outperform in MS estimation error (constraint-) LMS, RLS, orthogonal multistage decomposition and DL-SMI estimates.
- Data-record-based criteria for the selection of an AV estimator: a) maximum output J-divergence rule, and b) cross-validated minimum output variance rule.

AV filters: Best suited for

- High-dimensional adaptive signal processing applications that rely on data records of limited size.
- Rapidly changing communications environments.



Block diagram representation of the iteratively generated sequence of filters $\mathbf{w}_0, \mathbf{w}_1, \mathbf{w}_2, \ldots$

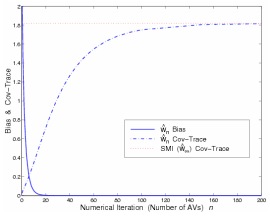
Input:
Autocovariance matrix $\mathbf{R}$, constraint vector $\mathbf{v}$, desired response $\mathbf{w}^H\mathbf{v} = \rho$.

Initialization:
$\mathbf{w}_0 := \frac{\mathbf{v}}{\|\mathbf{v}\|^2}\rho$.

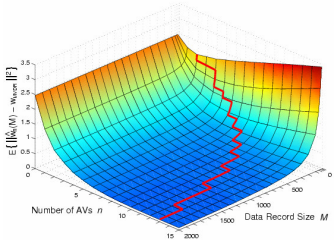
Iterative computation:
For $n=1, 2, \ldots$ do
begin
$\mathbf{g}_n := \left(\mathbf{I} - \frac{\mathbf{V}\mathbf{V}^H}{\|\mathbf{V}\|^2}\right)\mathbf{R}\,\mathbf{w}_{n-1}$
if $\mathbf{g}_n = \mathbf{0}$ then EXIT
$\mu_n := \frac{\mathbf{g}_n^H \mathbf{R}\,\mathbf{w}_{n-1}}{\mathbf{g}_n^H \mathbf{R}\,\mathbf{g}_n}$
$\mathbf{w}_n := \mathbf{w}_{n-1} - \mu_n \mathbf{g}_n$
end

Output:
Filter sequence $\mathbf{w}_0, \mathbf{w}_1, \mathbf{w}_2, \ldots$

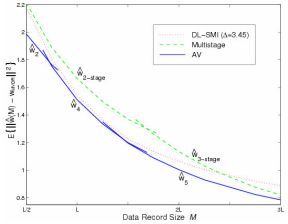
The algorithm for the iterative generation of the filter sequence $\mathbf{w}_0, \mathbf{w}_1, \mathbf{w}_2, \ldots$



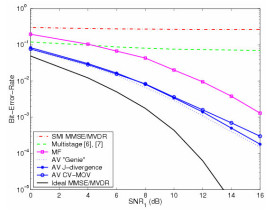
Norm-square bias and covariance trace for the sequence of filter estimators, n=0,1,…. (synchronous DS-CDMA system, processing gain L=32, K=13 users, SNR_1=12dB,$SNR_{2\text{-}13}$=0 {10dB, 12dB, 14dB}).



MS estimation error versus number of auxiliary vectors n and sample support M.



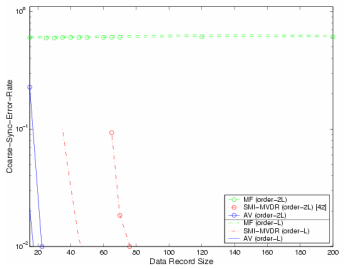
MS estimation error for the best multistage and AV estimators over the data support range M=0.5L=16 to M=3L=96. The MS estimation error of the Δ=3.45 DL-SMI estimator is also included as a reference.



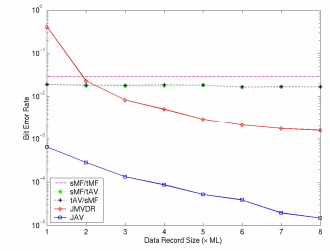
BER versus SNR for the user signal of interest (M=230). DS-CDMA multipath fading channel and narrowband antenna array reception. K=20 (SNR: 6-10dB), L=31, 3 paths, 5 antenna elements. 100 channel realizations and 10 independent data record regenerations per channel.

Applications

- Interference resistant rapid synchronization and combined demodulation of SS signals.
- Adaptive antenna arrays for interference resistant space-time processing of SS signals.
- Adaptive robust SS receivers (non-Gaussian, impulsive SS interference).
- Jam-resistant GPS.



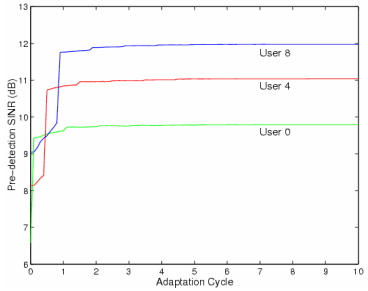
Coarse synchronization error rate as a function of the data record size. (Processing gain L=31, 10 interferers at SNR 10-28dB, Gold codes, random delays).



Bit-error-rate as a function of the data record size under multipath fading (total SNR_1 =15 dB, one jammer present) for a GPS system with M=2 antenna elements, processing gain L=1023 and the presence of K=4 satellite signals with fixed C/A Gold codes.

Future research

- Short-data-record performance prediction of adaptive receivers.
- Short-data-record convergence acceleration of adaptive non-linear systems with large number of parameters (eg. Neural networks).
- Adaptive assignment of binary DS-SS spreading codes.
- Optimum design of DS-CDMA binary spreading codes.
- Design of interference and multipath resistant signature waveforms for radar and communications systems.



Pre-detection SINR versus signature-set adaptation cycle for three users of the system (10 total users, 3 Rayleigh paths, code length 31, $SNR_{0\text{-}3}$=8dB, $SNR_{4\text{-}6}$=9dB, $SNR_{7\text{-}9}$=10dB).