Blind Equalization of IIR Channels using Hidden Markov Models

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Abstract — **A computationally inexpensive suboptimal blind equalization algorithm is presented for noisy IIR channels. It is based on combining a recursive Hidden Markov Model (HMM) estimator with a relaxed SPR (strictly positive real) Extended Least Squares (ELS) scheme. Simulation studies show that the algorithm yields satisfactory results.**

I. Signal Model

The observations y_k, $k = 1, 2, \dots, T$ are obtained as

$$y_k = \frac{s_k}{C(z^{-1})} + w_k, \quad w_k \sim N(0, \sigma_w^2) \qquad (1)$$

where w_k is zero mean white Gaussian noise (WGN) with variance σ_w^2.

$C(z^{-1}) = 1 - \sum_{i=1}^{p} c_i z^{-i}$ (where z^{-1} is the delay operator) denotes the *unknown* IIR channel. We assume that $C(z^{-1})$ is stable, i.e., it has all its zeros outside the unit circle.

s_k denotes a N-state discrete–time homogeneous first-order Markov chain. Consequently, the state s_k at time k is one of N *known* state levels $q = (q_1\ q_2 \dots q_N)'$. The transition probability matrix is $A = (a_{ij})$ where $a_{ij} = P(s_{t+1} = q_j | s_t = q_i)$. Of course $a_{ij} \geq 0$, $\sum_{j=1}^{N} a_{ij} = 1$, for each i. We assume that s_k is irreducible.

II. Algorithm Description

Our algorithm is termed the HMM-ELS Blind Equalization Algorithm. It combines a relaxed SPR ELS scheme [2] and recursive HMM estimator [1] resulting in a suboptimal computationally efficient recursive (on-line) scheme [3].

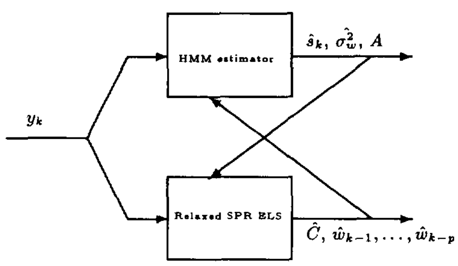


Figure 1: HMM-ELS Blind Equalization Algorithm

As shown in Fig.1, the HMM-ELS algorithm combines these two steps as follows:

1. At time k, the recursive HMM estimator yields estimate of the state of s_k, noise variance σ_w^2 and transition probabilities A.

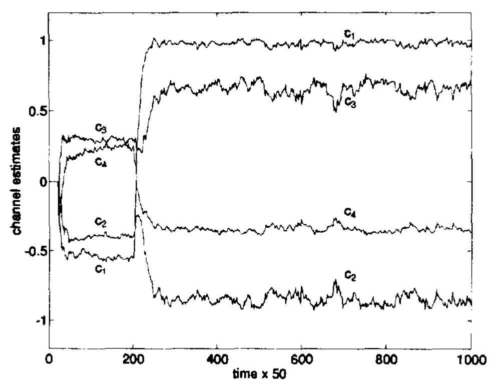
2. The relaxed SPR ELS estimator gives on-line estimates of the channel parameters c_i and w_{k-i}, $i \in \{1, 2, \dots, p\}$, denoted by $\hat{c}_i^{(k)}$ and $\hat{w}_{k-i}$ respectively.

III. Simulation Studies

Extensive simulation studies show that HMM-ELS yields excellent estimates even in low SNR [3]. It has been also shown in [3] that HMM-ELS performs better than Constant Modulus Algorithm (CMA). Here, we consider a jump time varying IIR(4) channel with coefficients

$$C = \begin{cases} (-0.5\ -0.4\ 0.3\ 0.2)' & 1 \leq k \leq 10000 \\ (1.0\ -0.9\ 0.7\ -0.36)' & 10000 < k \leq 50000 \end{cases} \qquad (2)$$

The input the channel is a two state markov chain with $a_{11} = a_{22} = 0.9$, $q_1 = -q_2 = 1$. Also $\sigma_w = 0.6$. Figure 2 shows how the HMM-ELS algorithm tracks the channel coefficients with a forgetting factor of $\lambda = 0.995$.



$\lambda = 0.995$

Figure 2: Equalization of "jump" time-varying channel

References

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