An Adaptive Filter with Gain and Time-shift Parameters for Echo Cancellation

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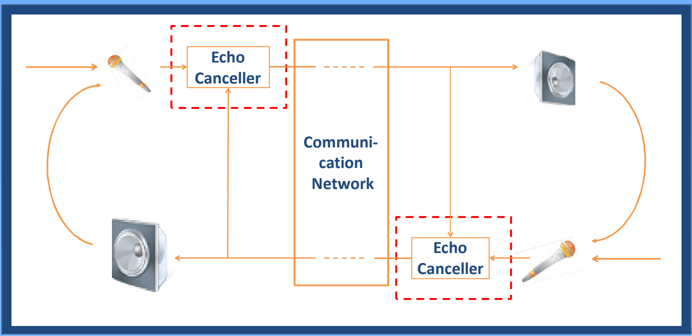
1. Introduction

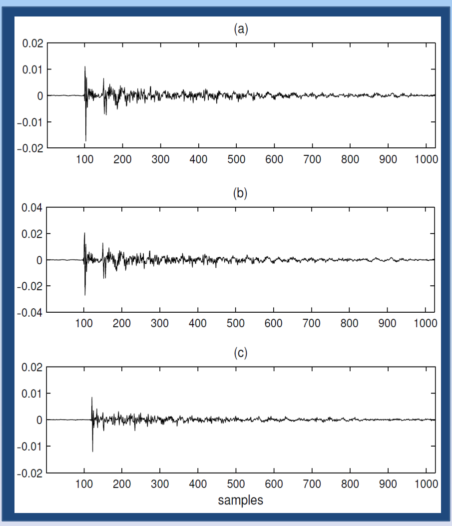


Motivation

To some hands-free acoustic systems, especially with separated loud-speakers and microphones, users would like to adjust the speakers volume or location. The adjustment may result in serious ***feedback howling*** if the changed echo path cannot be tracked in time.

2. Analysis of Echo Path Variation Caused by Loud-speaker Adjustment

The measurement was implemented in a quiet room (3m×6m) with a set of loudspeaker and micro-phone, and M-sequence method [11] was employed.



The First Case: h^1

The speaker volume is set to a certain value and located one meter away to the micro-phone

The Second Case: h^2

The volume is raised

The Third Case: h^3

The loudspeaker was moved one meter farther to the micro-phone while its volume is kept as the value in the first case

3. Parametric Adaptive Filter (PAF)

Z **domain expression**

$$w_k(z) = a_k \bar{w}_k(z) z^{\tau_k}$$

Time-shift parameter (τ_k)

Gain parameter (a_k)

Temporal domain expression

$$y(k) = a_k \bar{w}_k^T x_{k+\tau_k}$$

4. Adaptation Algorithm for PAF

Table 1: Adaptation Algorithm for PAF

Initialization:

$\bar{\mathbf{w}}_k = \mathbf{r}/||\mathbf{r}||$ $\quad$ $\mathbf{r}$ is a N-dim random vector.

$||\mathbf{x}_k||^2 = \sum_{i=0}^{k} x(i)^2$

a_k can be set as a reasonable positive value.

$\tau_k = 0 \qquad if\ 0 \le k < N$

Normalized filter update

$\bar{y}(k) = \bar{\mathbf{w}}_k^T \mathbf{x}_{k+\tau_k}$

$y(k) = a_k \bar{y}(k)$

$e(k) = d(k) - y(k)$

$||\mathbf{x}_{k+\tau_k}||^2 = ||\mathbf{x}_{k+\tau_k-1}||^2 + x(k+\tau_k)^2 - x(k+\tau_k-N)^2$

$c = \mu_{\bar{\mathbf{w}}} e(k)/a_k$

$\lambda_k = \sqrt{1 + 2c\bar{y}(k) + c^2||\mathbf{x}_{k+\tau_k}||^2}$

$\bar{\mathbf{w}}_{k+1} = (\bar{\mathbf{w}}_k + c\mathbf{x}_{k+\tau_k})/\lambda_k$

Gain update

$e(k)' = e(k)(1 - \mu_{\bar{\mathbf{w}}}||\mathbf{x}_{k+\tau_k}||^2)$

$a_{k+1} = a_k \lambda_k + \mu_a e'(k)\bar{y}(k)$

Delay update

$\hat{e}_k(\Delta\tau)^2 = (d(k - \Delta\tau + \tau_k) - y(k))^2$

$E_k(\Delta\tau) = (1 - \mu_\tau)E_{k-1}(\Delta\tau) + \mu_\tau \hat{e}_k(\Delta\tau)^2$

$\hat{\tau}_k = \mathrm{argmin}_{\Delta\tau}\ E_k(\Delta\tau) \qquad -D \le \Delta\tau \le D$

If $\hat{\tau}_k$ has kept invariant more than a duration

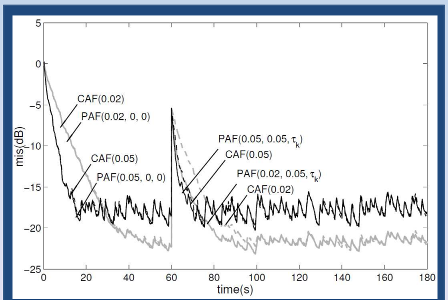
$\tau_{k+1} = \hat{\tau}_k$

5. Experiment

$$mis(k) = 20\log_{10}(\| h_k - \hat{h}_k \| / \| h_k \|)$$

Gain changing scenario

The transfer function used in this scenario is switched from h^1 to h^2 at the 60*th* second



Gain and delay changing scenario

The transfer function used in this scenario is switched from h^1 to h^2 at the 60*th* second