Adaptive Echo Cancellation

*The APA Algorithm*

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Definition Of Terms

• APA – Affine Projection Algorithm

The APA algorithm can be viewed as a generalization of the NLMS algorithm, where the NLMS algorithm would be a one dimensional projection.

• $x_n = [x_n, x_{n-1}, \ldots, x_{n-L+1}]^T$

The excitation or “training” vector.

• $s_n$

Echo plus near-end speech and background noise.

• $h_n = [h_{0,n}, h_{1,n}, \ldots, h_{L-1,n}]^T$

The filter coefficient vector, where $h_{i,n}$ is the $i$th tap weight at time $n$.

• $e_n$

The error signal or residual echo.
FAP Diagram

Echo Canceller

From Far-End Talker

Near-End Speech

To Far-End Talker

Echoes

\( h_n \)

\( x_n \)

\( r_n \)

\( e_n \)

\( s_n \)
Adaptive Transversal Filter

Echo Canceller

From Far-End Talker

\[ x_n, x_{n-1}, x_{n-2}, \ldots, x_{n-N+1} \]

To Far-End Talker

\[ h_{0,n}, h_{1,n}, h_{2,n}, \ldots, h_{N-1,n} \]

Echoes

Near-End Speech

\[ e_n, s_n \]
APA Algorithm(1)

The APA algorithm is described by the following two equations.

\[ e_n = s_n - X_n^T h_{n-1} \]  \hspace{1cm} (0)

\[ h_n = h_{n-1} + \mu X_n \left[ X_n^T X_n \right]^{-1} e_n \]  \hspace{1cm} (1)
APA Algorithm(2)

The excitation signal at time $n$ is given by

$$\underline{x}_n = [x_n, x_{n-1}, \ldots, x_{n-L+1}]^T$$  \hspace{1cm} (2)

Where $L$ is the length of the tap-delay line (FIR filter). Then the $L \times N$ excitation matrix is given by.

$$X_n = [\underline{x}_n, \underline{x}_{n-1}, \ldots, \underline{x}_{n-N+1}]$$  \hspace{1cm} (3)

Where $N$ is the dimension of the projection.
APA Algorithm (3)

The normalized residual echo vector is calculated using the following equations.

\[ h_n = [h_{0,n}, h_{1,n}, \ldots, h_{L-1,n}]^T \]  \hspace{1cm} (5)

Where \( h_{i,n} \) is the \( ith \) coefficient at time \( n \).

The vector \( s \) is the near end (microphone) signal.

\[ s_n = [s_n, s_{n-1}, \ldots, s_{n-N+1}]^T \]  \hspace{1cm} (6)

The vector \( s_n \) contains the near-end signal over \( N \) time samples.
APA Algorithm(4)

The error vector is given by

\[
e_n = [e_n, e_{n-1}, \ldots, e_{n-N+1}]^T
\]  

(7)

Where

\[
e_n = s_n - x_n^T h_n
\]  

(8)
APA Algorithm (5)

If $N$ is set to 1 in equations (0) and (1), the APA algorithm becomes the NLMS algorithm.

\[ e_n = s_n - x_n^T h_n \]  \hspace{1cm} (9)

\[ h_n = h_{n-1} + \mu x_n \left[ x_n^T x_n \right]^{-1} e_n \]  \hspace{1cm} (10)
Real World APA Performance

- Convergence like RLS convergence (fast)[1]

Figure 2. Comparison of FAP for different orders of projection, \( N \), with speech excitation.
Real World APA Performance

- Complexity \(2LN + K_{inv}N^2\) [1]. Where \(K_{inv}\) is a constant associated with the inverse required. If a Levinson algorithm is used, \(K\) is about 7.
- Only fast converging for colored signals, like speech.
References

