Robust Feedback Active Noise Control Algorithm for Impulsive Additive Noise

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Abstract: In this paper, robust feedback ANC(Active Noise Control) algorithm is proposed when impulsive additive noise is present. Instead of using the conventional LMS(Least Mean Square) algorithm, PSA(Proportion-Sign Algorithm) is adopted to estimate the primary noise field robustly when the additive noise is impulsive. Performance comparison between the conventional feedback ANC algorithm and the proposed one is shown by computer simulations.

INTRODUCTION

Feedback ANC system creates quiet zone using feedback control of a secondary source which is located in the vicinity of an error sensor. It uses only one sensor to get the information about the reference signal and the error signal and can be interpreted as a M-th order predictor where M is the filter order of the estimated secondary path. Using only one error sensor, it has the merit to avoid the acoustic feedback from the canceling speaker to the reference sensor. Filtered-x LMS algorithm is a modified version of the LMS algorithm to consider the acoustic path between the secondary noise source and the error sensor and has been widely used in ANC algorithm for its simplicity of implementation and good performance[1].

On the other hand, when there is the additive noise that is impulsive, the performance of the LMS-type algorithm is known to be degraded[2]. To be robust for this phenomenon, we propose a new feedback ANC algorithm when the additive noise is impulsive. Instead of using LMS algorithm, PSA which is a mixture of LMS and DSA(Dual-Sign Algorithm) is used to predict the desired noise signal robustly.

Computer simulations were performed under the impulsive noise circumstances and showed better performance with the proposed algorithm than that with the conventional filtered-x LMS algorithm.

ROBUST FEEDBACK ACTIVE NOISE CONTROL ALGORITHM

Fig. 1 shows the block diagram of the feedback ANC system. Modeling the secondary path as pure time delays, feedback ANC system can be analyzed as a M-th order predictor where M is the number of delay. Therefore, the filter output \( r(t) \) is the M-th order predicted value of the noise source \( s(t) \). The generation of \( r(t) \) is equivalent to the estimation of the AR parameters. The AR parameters can be adaptively estimated by filtered-x LMS algorithm.

\[
\begin{align*}
\text{AR Process:} & \quad s(t) \\
\text{Predictor:} & \quad r(t) = \sum_{k=0}^{M} a_k s(t-k) \\
\text{Cancellation Algorithm:} & \quad e(t) = s(t) - r(t)
\end{align*}
\]

\[e(t) = s(t) - r(t)\]

However, the conventional filtered-x LMS algorithm has the defect over the impulsive noise for its influence function is not bounded with respect to the estimation error. Impulsive noise can be appropriately modeled by contaminated gaussian process having the probability density function

\[
P_e = (1 - \varepsilon) P_{\mu_1} + \varepsilon P_{\mu_2}
\]

where \( 0 \leq \varepsilon \leq 0.5 \) is contamination constant, \( P_{\mu_1} \) is zero mean gaussian probability density and \( P_{\mu_2} \) is contaminating probability density.

Because of the above mentioned drawback of conventional algorithm, there should be alternative method to overcome this defect. Proposed algorithm that can resolve this shortcomings utilizes PSA that bounds the absolute
value of the prediction error in weight update. In PSA, the update equation is given by
\[ W(t+1) = W(t) - 2\mu \varphi(m(t)) E(t) \]  
(2)
where
\[ \varphi(m(t)) = \begin{cases} m(t) & |m(t)| \leq \tau \\ L \text{sign}(m(t)) & |m(t)| > \tau \end{cases} \]  
(3)
is the influence function, or derivative of the cost function and called modified Huber function and \( E(t) \) is input vector. In eq.(3) \( L \) and \( \tau \) are the pre-selected constants such that \( L \geq \tau \geq 0 \), and \( \text{sign}(\cdot) \) denotes the signum function. Since PSA has the flexible parameters \( L \) and \( \tau \) as well as \( \mu \), convergence speed of PSA can be more adjustable than that of LMS. Note from eq.(3), the PSA becomes LMS in case of \( |m(t)| \leq \tau \) so that its steady-state performance can be expected to become that of LMS. On the other hand, when the absolute value of estimation error is larger than \( \tau \), i.e. additive noise is impulsive, PSA bounds its amplitude to \( L \) so that it can have the advantage of robustness to the impulsive additive noise.

SIMULATIONS

In our simulations, we assumed the order of AR process to be one with two sets of condition. Simulated system of each AR parameter is 1. \( \alpha = -0.99, \sigma^2 = 0.9363 \) 2. \( \alpha = +0.99, \sigma^2 = 0.9363 \) respectively. The SNR between \( s(t) \) and \( v(t) \) is set to be 26 dB which corresponds to fixing \( \sigma_v \) at 5% of the standard deviation of the desired signal. The propagation delay \( M \) is one. Fig. 2(a) is for the single impulse and fig.2(b) is for the impulsive noise with \( \varepsilon = 0.05, \sigma_{\varepsilon} = 15\sigma_v \). The convergence constant is \( \mu = 0.05 \).

CONCLUSION

From the simulations, we could observe faster convergence speed with the proposed algorithm than that with the conventional one in weight update by proper choice of \( L \) and \( \tau \). For future work, exact analysis of pre-selected parameters and application to the real noise signal with impulsive noise should be carried out.

REFERENCES