Dipartimento di Elettronica e Informazione
POLITECNICO DI MILANO

Active Noise Control
course notes (January 2015)
Suggested problems

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Fast affine projection algorithm

Prepare a literature review on affine projection algorithms.

Implement in Matlab the FAP algorithm and compare it with the FxLMS both on narrowband and broadband problems.

References:

- S. C. Douglas, "The Fast Affine Projection Algorithm for Active Noise Control", *Proceedings of ASILOMAR-29*, pp. 1245–1249, 1996.
- M. Bouchard, "Multichannel Affine and Fast Affine Projection Algorithms for Active Noise Control and Acoustic Equalization Systems", *IEEE Transactions on Speech and Audio Processing*, vol. 11, n. 1, pp. 54–60, 2003.

Fast exact adaptive algorithm

Prepare a literature review on the fast exact adaptive algorithm.

Implement in Matlab the fast exact adaptive algorithm and compare it with the FxLMS both on narrowband and broadband problems.

References:

- D.S. Nelson, S.C. Douglas, and M. Bodson, "Fast exact adaptive algorithms for feedforward active noise control", *Int. J. Adapt. Control Signal Process.*, vol. 14, pp. 643–661, 2000.

FxdLMS algorithm

Implement in Matlab the FxdLMS algorithm and compare it with the FxLMS both on narrowband and broadband problems.

References:

- X. Sun and D.-S. Chen, "A new infinite impulse response filter-based adaptive algorithm for active noise control", *Journal of Sound and Vibration*, vol. 258, n.2, pp. 385–397, 2002.

Role of the commutation error

Evaluate in simulation the role of the commutation error in ANC problems.

References:

- C.-W. Liao and J.-Y. Lin, "New FIR filter-based adaptive algorithms incorporating with commutation error to improve active noise control performance", *Automatica*, vol. 43, pp. 325–331, 2007.
- J.-Y. Lin and C.-W. Liao, "New IIR filter-based adaptive algorithm in active noise control applications: Commutation error-introduced LMS algorithm and associated convergence assessment by a deterministic approach", *Automatica*, vol. 44, pp. 2916–2922, 2008.

Tracking of multi-harmonic signals 1

Compare the methods in the listed references for the rejection of a bi-harmonic signal, varying the initial frequencies of the filters, and the relative amplitudes and distance in frequency of the harmonic components of the disturbance.

Test also the ability to track a harmonic signal with linearly increasing frequency.

References:

- P.A. Regalia, "An improved lattice-based adaptive IIR notch filter", *IEEE Trans. on Signal Processing*, vol. 39, n. 9, pp. 2124–2128 1991.
- M. Bodson and S.C. Douglas, "Adaptive algorithms for the rejection of periodic disturbances with unknown frequency", *Automatica*, vol. 33, n. 12, pp. 2213–2221, 1997.

Tracking of multi-harmonic signals 2

Compare the methods in the listed references for the rejection of a bi-harmonic signal, varying the initial frequencies of the filters, and the relative amplitudes and distance in frequency of the harmonic components of the disturbance.

Test also the ability to track a harmonic signal with linearly increasing frequency.

References:

- J.E. Cousseau, S. Werner, and P.D. Donáte, "Factorized All-Pass Based IIR Adaptive Notch Filters", *IEEE Trans. on Signal Processing*, vol. 55, n. 11, pp. 5225–5236, 2007.
- R. Marino and P. Tomei, "Global Estimation of Unknown Frequencies", *IEEE Transactions on Automatic Control*, vol. 47, n. 8, pp. 1324–1328, 2002.

Attenuation of harmonic signals in the presence of errors in the frequency estimation

The listed reference studies the attenuation of sinusoidal disturbances in the presence of errors in the estimation of the disturbance frequency. Study the proposed method, implement the algorithm in Matlab and repeat the simulations documented in the paper. Compare the method with a standard adaptive notch filtering scheme.

References:

- H.-J. Jeon, T.-G. Chang, S. Yu, and S.M. Kuo, "A Narrowband Active Noise Control System With Frequency Corrector," *IEEE Transactions on Audio, Speech, and Language Processing*, vol. 19, n. 4, pp. 990–1002, May 2011.

Tracking and attenuation of harmonic signals with non-constant frequency

Consider a disturbance $d(t) = \sin(2\pi f(t)t)$, where $f(t) = f_0 + n(t)$, f_0 being a costant and $n(t)$ a noise term, *e.g.* $n(t) = N \sin(2\pi f_n t)$, with $f_n << f_0$, and $N \in \{0, 0.001f_0, 0.01f_0, 0.1f_0\}$. Study the problem of attenuating the disturbance with an adaptive filter scheme (use plain LMS with FIR filters and adaptive notch filters), assuming that: a) $f(t)$ is known, b) $f(t)$ is estimated as $\hat{f}(t) = f_0$, c) $f(t)$ is estimated using Regalia's scheme. Study, in particular, how f_n affects the overall noise attenuation performance.

Parallel Narrowband ANC Systems

Conventional parallel-form narrowband active noise control (ANC) systems use multiple adaptive filters that are updated by the same error signal. In the considered paper a different, suitably filtered error signal is used to tune each adaptive filter. Study the proposed method, implement the algorithm in Matlab and repeat the simulations documented in the paper. Verify also the critique in the 2nd paper.

References:

- C.-Y. Chang and S. M. Kuo, "Complete Parallel Narrowband Active Noise control systems", *IEEE Transactions on Audio, Speech, and Language Processing,* vol. 21, no. 9, pp. 1979-1986, Sept. 2013.
- J. Cheer and S. J. Elliott, "Comments on "Complete Parallel Narrowband Active Noise Control Systems", *IEEE/ACM Transactions on Audio, Speech, and Language Processing*, vol. 22, no. 5, May 2014.

Subband adaptive filters

Prepare a literature review on subband adaptive filters. Implement in Matlab the subband filter suggested in the listed reference and compare it with the FxLMS on a broadband problem.

References:

- D.R. Morgan and J.C. Thi, "A Delayless Subband Adaptive Filter Architecture", *IEEE Transactions on Signal Processing*, vol. 43, n. 8, pp. 18–19, 1995.

MPC applied to ANC

Implement in Matlab the MPC-based ANC method suggested in the listed reference and compare it with the FxLMS on both broadband and narrowband problems.

References:

- Q.-Z. Zhang and W.-S. Gan, "A model predictive algorithm for active noise control with online secondary path modelling", *Journal of Sound and Vibration*, vol. 270, pp. 1056–1066, 2004.

Attenuating disturbances uncorrelated with the reference signal

Disturbances that are uncorrelated with the reference signal cannot be attenuated by the standard FXLMS algorithm. Study the method proposed in the reference to address this problem. Code the proposed algorithm in Matlab and repeat the simulations illustrated in the paper to verify their correctness.

References:

- M.T. Akhtar and W. Mitsuhashi, "Improving Performance of Hybrid Active Noise Control Systems for Uncorrelated Narrowband Disturbances," *IEEE Transactions on Audio, Speech, and Language Processing*, vol.19, n.7, pp. 2058–2066, Sept. 2011.