

應用適應性濾波演算法則於車輛回音消除及故障訊號分析

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摘要

本研究應用適應性濾波演算法則於車輛視聽系統回音消除以及故障訊號分析。本論文分為三部分，第一部份為改善車廂內聲學回授效應；本研究以適應性演算法則來消除車廂內聲學回授效應，過去，大多數的視聽系統回音消除都是以傳統最小均方誤差演算法（LMS）為基礎，但其收斂速度不理想，故本研究利用可變收斂因子演算法（VSS APA），使收斂因子可根據系統得到理想值。第二部分，應用適應性線性增強系統（Adaptive Line Enhancement）於轉動機械故障訊號分析，可藉由轉動機械的聲音及振動訊號來判別機械是否故障；由於量測到的訊號通常不一定單純只有轉動機械的訊號，往往還會量測到其他不需要的訊號，在這裡稱為雜訊（noise），如環境的背景噪音等。為了有效將背景噪音消除，得到所需要的故障訊號，提出線性增強系統可降低環境的背景噪音。大部分線性增強系統都以最小均方誤差演算法（LMS）為基礎，本研究利用可變收斂因子仿射投影演算法則的收斂因子可達到理想值為優點，應用在線性增強系統。本研究第三部份，應用兩階段適應性濾波器系統（Two-Stage Adaptive Filtering System）對引擎冷卻風扇作故障訊號分析。由於引擎冷卻風扇裝設位置在引擎旁，在量測冷卻風扇聲音訊號時，不僅量測到風扇聲音同時也會連引擎噪音以及環境背景噪音（如車體的震動聲音）也接收進來。這些干擾的噪音可分為兩種一種是窄頻的引擎噪音，另一種為寬頻噪音，如車體的振動噪音。為解決這些問題，提出了兩階段適應性濾波器系統，這個系統結合了傳統適應性濾波器的優點以及線性增強系統的優 -v 勢，適應性濾波器的雜訊消除可消除單頻噪音，線性增強系統可降低寬頻噪音。本研究應用的演算法結合仿射投影演算法(APA)和可變收斂因子最小均方演算法(VSS LMS)的優點，因為仿射投影演算法輸入訊號為矩陣，比傳統演算法輸入為向量的資料更完整，使預測的權重向量更準確又快速。但由於仿射投影演算法的收斂因子為固定的，本研究利用發展完整的可變收斂因子最小均方演算法來調整收斂因子，使收斂因子可根據系統得到最理想值。為了驗證本研究所提出之可變收斂因子仿射投影演算法的效果，則將可變收斂因子仿射投影演算法與傳統演算法模擬比較，結果顯示可變收斂因子仿射投影演算法性能較優越並且適合用於本研究系統中。

關鍵詞：聲學回授，適應性濾波器，線性增強，故障診斷，可變收斂因子仿射投影演算法

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參考文獻

- [1] S. K. Lee and P. R. White, "The enhancement of impulsive noise and vibration signals for fault detection in rotating and reciprocating machinery," *Journal of Sound Vibration*, Vol. 271, pp. 485-505, May, 1998.
- [2] B. Widrow and J. M. McCool, "Stationary and nonstationary learning characteristics of the LMS filter," *Proc. IEEE*, Vol. 64, pp. 1151-1162, 1976.
- [3] B. Widrow and M. E. Hoff, "Adaptive switching circuits," *IRE Western Electric Show and Convention Record*, pp. 96-104, 1960.
- [4] B. Widrow and S. D. Stearns, "Adaptive signal Processing," Englewood Cliffs, New Jersey, Prentice-Hall, 1985.
- [5] S. Haykin, "Adaptive Filter Theory," 3rd ed. Englewood Cliffs, New Jersey, Prentice-Hall, 1996.
- [6] G. Roulrier and C. Galand, "An echo cancellation algorithm for operation with a digital speech coder in a single signals processor," *Proc. IEEE ICASSP 88*, pp. 1628-1631, 1988.
- [7] R. W. Harris and D. Chabries, F. Bishop, "A variable step (VS) adaptive filter algorithm," *IEEE Trans. Acoustics, Speech, and Signal Processing*, Vol. 34, pp. 309-316, 1986.
- [8] R. H. Kwong and E. W. Johnston, "A variable step size LMS algorithm," *IEEE Trans. Signal Processing*, Vol. 40, pp. 1633-1641, 1992.
- [9] T. Aboulnasr and K. Mayyas, "A robust step-size LMS-type algorithm: analysis simulations," *IEEE Trans. Signal Processing*, Vol. 45, pp. 631-639, 1997.
- [10] P. Sristi, W. S. Lu and A. Antoniou, "A new variable-step-size LMS algorithm and its application in subband adaptive filtering for echo cancellation," *Proc. IEEE ISCAS 01*, Vol. 2, pp. 721-724, 2001.
- [11] J. T. Rickard and J. R. Zeidler, "Second-order output statistics of the adaptive line enhancer," *IEEE Trans. Acoustics, Speech and signal processing*, Vol. ASSP-27, pp. 31-39, No. 1, Jan. 1991.
- [12] B. Widrow, J. R. Glover, J. M. McCool, J. Kaunitz, C. S. Williams, R. H. Hear, J. R. Zeidler, J. E. Dong and R. C. Goodlin, "Adaptive noise cancelling: Principles and applications," *Proc. IEEE*, Vol. 63, pp. 1692-1716, 1975.
- [13] J. R. Zeidler, "Performance analysis of LMS adaptive prediction filters," *Proc. IEEE*, Vol. 78, pp. 1781 – 1806, Dec. 1990.
- [14] H. Ding, J. Lu, X. Qiu and B. Xu, "An adaptive speech enhancement method for siren noise cancellation," *Applied Acoustics Proc.*, Vol. 65, pp. 385-399, 2004.
- [15] M. Ghogho, M. Ibnkahla and N. J. Bershad, "Analytic behavior of the LMS adaptive line enhancer for sinusoid corrupted by multiplicative and additive noise," *IEEE Trans. Signal Processing*, Vol. 46, pp. 2386-2393, 1998.
- [16] R. L. Campbell Jr., N. H. Younan and J. Gu, "Performance analysis of the adaptive line enhancer with multiple sinusoid in noisy environment," *Signal Processing*, Vol. 82, pp. 93-101, Jan. 2002.
- [17] Y. Guo, J. Zhao and H. Chen, "A novel algorithm for underwater moving-target dynamic line enhancement," *Applied Acoustics*, Vol. 64, pp. 1159-1169, 2003.
- [18] W. Hernandez, "Improving the response of a wheel speed sensor using an adaptive line enhancer," *Measurement*, Vol. 33, pp. 229-240, 2003.
- [19] W. Hernandez, "Improving the response of an accelerometer by using optimal filtering," *Sensors and Actuators*, Vol. A88, pp. 198-208, Oct. 2000.
- [20] R. N. Brady, "Automotive electric and computer system," Englewood Cliffs, New Jersey, Prentice-Hall, 2000.
- [21] J. Shiroishi, Y. Li, S. Liang, T. Kurfess and S. Danyluk, "Bearing condition diagnosis via vibration and acoustic emission measurements," *Mechanical System Signal Proc.*, Vol. 11, pp. 693-705, 1997.
- [22] K. Shibata, A. Takahashi and T. Shirai, "Fault diagnosis of rotating machinery through visualization of sound signal," *Mechanical System Signal Proc*, Vol. 14, pp. 229-241, 2000.
- [23] C. F. N. Cowan and P. M. Grant, "Adaptive filter," Englewood Cliffs, New Jersey, Prentice-Hall, 1985.
- [24] C. M. Anderson, E. H. Satorius and J. R. Zeidler, "Adaptive enhancement of bandwidth signals in white Gaussian noise," *IEEE Trans. Acoustics, Speech, Signal processing*, Vol. ASSP-31, pp.17-28, 1983.
- [25] Y. Yoganandam, V. U. Reddy and T. Kailath, "Performance analysis of the adaptive line enhancer for sinusoidal signals in broad-band noise," *IEEE Trans. Acoustics, Speech and Signal Processing*, Vol. 36, No. 11, pp.1749-1757, 1988.
- [26] J. R. Treichler, "Transient and convergent behavior of adaptive line enhancer," *IEEE Trans. Acoustics, Speech and Signal processing*, Vol. ASSP-26, No. 1, pp.53-62, 1979.

- [27] C. E. Davila, A. Abaya and A. Khotanzad, " Estimation of single sweep steady-state visual, " IEEE Trans. Biomedical engineering. Vol. 41, No. 2, pp.197-200, 1994.
- [28] S. K. Lee and P. R. White, " Fault diagnosis of rotating machinery using a two-stage adaptive enhancer, " IEE Colloquium on Modelling and signal processing for fault diagnosis, No. 260, pp. 1/6-6/6, 1996.
- [29] D. T. M. Slock and T. Kailath, " Numerically stable fast transversal filters for recursive least squares adaptive filter, " IEEE Trans. Signal Processing, Vol. 39, pp. 92-114, 1991.
- [30] I. Nakanishi and Y. Fukui, " A new adaptive convergence factor algorithm with the constant damping parameter, " IEICE Trans. Fundamentals, Vol. E78-A, pp. 649-655, 1995.
- [31] F. Casco, H. Perez, M. Nakano and M. Lopez, " A variable step size (VSS-CC) NLMS algorithm, " IEICE Trans. Fundamentals, Vol. E78-A, pp. 1004-1009, 1995.
- [32] V. J. Mathews and Z. Z. Xie, " A stochastic gradient adaptive filter with gradient adaptive step size, " IEEE Trans. Signal Processing, Vol.41 pp. 2075-2087, 1992.
- [33] J. Okello, Y. Itoh, Y. Fukui, I. Nakanishi and M. Kobayashi, " A new modified variable step size for the LMS algorithm, " Proc. IEEE ISCAS 98, Vol. 5, pp. 170-173, 1998.
- [34] L. Youhong and J. M. Morris, " Gabor expansion for adaptive echo cancellation, " IEEE Signal Processing Magazine, Vol. 16 pp. 68-80, 1999.
- [35] A. N. Birkett and R. A. Goubran, " Acoustic echo cancellation for hands-free telephony using neural networks, " Proc. IEEE ICNNSP 94, pp. 249-258, 1994.
- [36] C. O. Nwagboso, " Automotive sensory system, " London: Chapman and Hall, 1993.
- [37] J. Erjavec and R. Scharff, " Automotive technology, " New York: Delmar Publishers, 1996.
- [38] J. D. Halderman, " Automotive chassis systems: brakes, steering, suspension and alignment, " Englewood Cliffs, New Jersey, Prentice-Hall, 1996.
- [39] J. D. Halderman and H. E. Ellinger, " Automotive engines: theory and servicing, " 3rd ed. New Jersey: Prentice-Hall, 1997.
- [40] M. J. Nunney, " Light and Heavy vehicle technology, " 2nd ed. Oxford: Butterworth-Heinemann Ltd, 1992.
- [41] J. F. Dagel, " Diesel engine and fuel system repair, " 3rd ed. Englewood Cliffs, New Jersey, Prentice-Hall, 1994.