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Performance analysis of the self-orthogonalising adaptive lattice filter

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Abstract

This paper describes new self-orthogonalising adaptive lattice filter (SALF) structures to enhance slow convergence rates caused by eigenvalue spread. Firstly, we propose the variable stepsize self-orthogonalising adaptive lattice filtering (VSALF) structure to speed up the convergence rate of partial correlation (PARCOR) coefficients. Secondly, the partial self-orthogonalising adaptive lattice filtering (PSALF) structure is proposed in order to enhance the tracking ability for nonstationary environments. Moreover, the PSALF structure can reduce computational complexity whilst maintaining a fast convergence rate. A performance analysis based on the convergence model of the lattice predictor is given in terms of mean-squared error and variance of the PARCOR coefficient error. Computer simulations are undertaken to verify the performance and applicability of the proposed filter structures. © 2000 Elsevier Science B.V. All rights reserved.

Zusammenfassung

Diese Arbeit beschreibt neue selbstorthogonalisierende adaptive Lattice-Filter (SALF) Strukturen, welche eine Verbesserung von durch Eigenwertstreuung verursachten langsamen Konvergenzraten bewirken. Zunächst schlagen wir die Struktur der selbstorthogonalisierenden adaptiven Lattice-Filterung mit variabler Schrittweite (VSALF) vor, durch die die Konvergenzrate von Koeffizienten partieller Korrelation (PARCOR) beschleunigt wird. Weiters stellen wir die partielle selbstorthogonalisierende adaptive Lattice-Filter (PSALF) Struktur vor, welche die Nachführeigenschaften für nichstationäre Umgebungen verbessert. Darüber hinaus kann die PSALF-Struktur bei Bewahrung schneller Konvergenz den Rechenaufwand reduzieren. Hinsichtlich des mittleren quadratischen Fehlers und der Varianz des PARCOR-Koeffizientenfehlers wird eine auf dem Konvergenzmodell des Lattice-Prädiktors beruhende Leistungsanalyse durchgeführt. Die Leistungsfähigkeit und Anwendbarkeit der vorgeschlagenen Filterstrukturen werdern mittels Computersimulationen verifiziert. © 2000 Elsevier Science B.V. All rights reserved.

Résumé

Cet article décrit des structures nouvelles pour les filtres en treillis adaptifs auto-orthogonalisants (SALF) permettant d'améliorer les taux de convergence lents dus à la dispersion des valeurs propres. Nous proposons premièrement la structure de filtrage en treillis adaptatif auto-orthogonalisant à pas variable (VSALF) pour accélérer le taux de convergence des coefficients de corrélation partielle (PARCOR). Nous proposons ensuite la structure de filtrage en treillis adaptatif auto-orthogonalisant partiel (PSALF), qui permet d'améliorer les capacités de poursuite dans les environnements non-stationnaires. De plus, la structure PSALF peut avoir une complexité de calacul réduite tout en maintenant

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une taux de convergence élevé. Nous présentons une analyse des performances basée sur le modèle de convergence du prédicteur en treillis en termes d'erreur quadratique moyenne et de variance de l'erreur sur les coefficients PARCOR. Des simulations sur ordinateur permettant de vérifier les performances et l'applicabilité des structures de filtre proposées sont également décrites.

Keywords: Adaptive filter; Self-orthogonalising adaptive lattice filter (SALF); PARCOR coefficient

1. Introduction

Adaptive filtering algorithms based on the stochastic gradient method are widely used in many applications such as system identification, noise cancellation, active noise control and communication channel equalisation. These algorithms have attracted the attention of many researchers because of their low complexity and robustness to implementation error [11]. However, the eigenstructure of the correlation matrix of a transversal filter's tap input signal has a profound impact on the convergence behaviour of the least mean-squares (LMS) algorithm. When the tap input signals are drawn from a white noise process, they are uncorrelated and the eigenvalue spread of the correlation matrix is unity, with the result that the LMS algorithm has a nondirectional convergence. At the other extreme, when the tap input signals are highly correlated, the LMS algorithm takes on a directional nature which results in a slow convergence [6,12].

Our approach to resolve the eigenvalue spread problem is explained briefly in Fig. 1. The plant model extends the concept of the transform domain adaptive filter [2,20,25] by combining an adaptive lattice predictor and a linear combiner. Henceforth, this structure is described as the self-orthogonalising adaptive lattice filter (SALF). This filter structure has previously been referred to as joint process estimator, it was first developed by Griffiths [8,9] to be used in a multichannel noise canceling application, but, focus was not placed on the theoretical analysis.

Similar filtering structures using a prewhitening scheme have already been developed in [5,23,24,27]. In [23], Mboup proposed the prewhitening filter structure to speed up convergence rates. This work employed a simple LMS predictor to decorrelate the input signal. In this case, the input signal was modelled as a stationary complex sinusoidal signal in a broad-band noise background to make the theoretical analysis simple. Proudler [27] proposed the preconditioning LMS filtering structure based on the conventional lattice predictor. The performance was judged purely by computer simulation. Other related work was

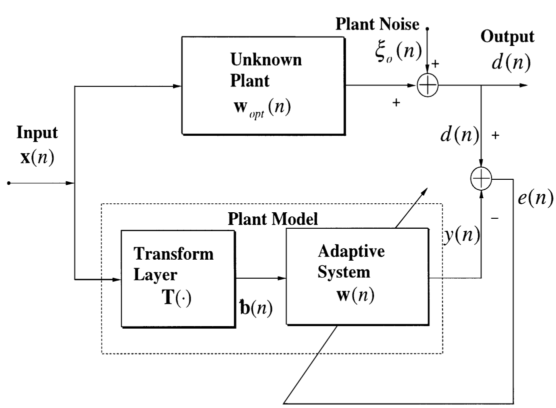

Fig. 1. Block diagram of adaptive plant modelling.