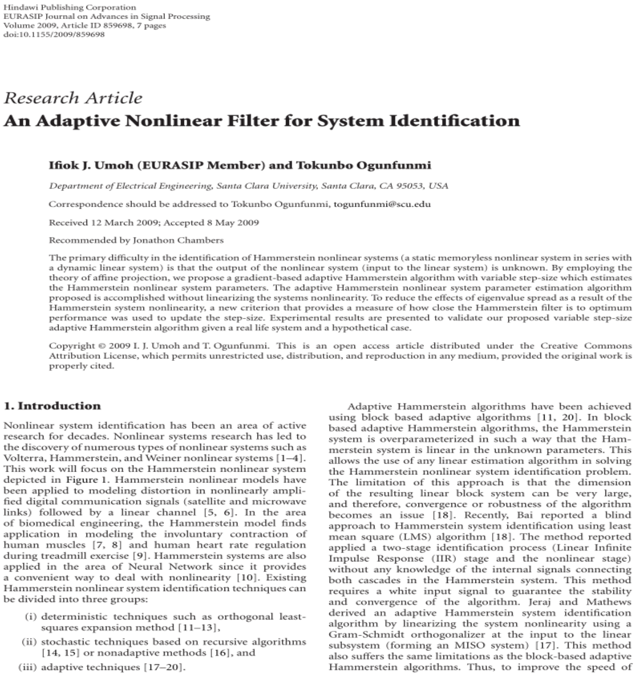
Adaptive Nonlinear System Identification: The Volterra and Wiener Model Approaches (Signals and Comm



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Research Article

An Adaptive Nonlinear Filter for System Identification

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The primary difficulty in the identification of Hammerstein nonlinear systems (a static memoryless nonlinear system in series with a dynamic linear system) is that the output of the nonlinear system (input to the linear system) is unknown. By employing the theory of affine projection, we propose a gradient-based adaptive Hammerstein algorithm with variable step-size which estimates the Hammerstein nonlinear system parameters. The adaptive Hammerstein nonlinear system parameter estimation algorithm proposed is accomplished without linearizing the systems nonlinearity. To reduce the effects of eigenvalue spread as a result of the Hammerstein system nonlinearity, a new criterion that provides a measure of how close the Hammerstein filter is to optimum performance was used to update the step-size. Experimental results are presented to validate our proposed variable step-size adaptive Hammerstein algorithm given a real life system and a hypothetical case.

1. Introduction

Nonlinear system identification has been an area of active research for decades. Nonlinear systems research has led to the discovery of numerous types of nonlinear systems such as Volterra, Hammerstein, and Weiner nonlinear systems [1–4]. This work will focus on the Hammerstein nonlinear system depicted in Figure 1. Hammerstein nonlinear models have been applied to modeling distortion in nonlinearly amplified digital communication signals (satellite and microwave links) followed by a linear channel [5, 6]. In the area of biomedical engineering, the Hammerstein model finds application in modeling the involuntary contraction of human muscles [7, 8] and human heart rate regulation during treadmill exercise [9]. Hammerstein systems are also applied in the area of Neural Network since it provides a convenient way to deal with nonlinearity [10]. Existing Hammerstein nonlinear system identification techniques can be divided into three groups:

(i) deterministic techniques such as orthogonal least-squares expansion method [11–13],
(ii) stochastic techniques based on recursive algorithms [14, 15] or nonadaptive methods [16], and
(iii) adaptive techniques [17–20].

Adaptive Hammerstein algorithms have been achieved using block based adaptive algorithms [11, 20]. In block based adaptive Hammerstein algorithms, the Hammerstein system is overparameterized in such a way that the Hammerstein system is linear in the unknown parameters. This allows the use of any linear estimation algorithm in solving the Hammerstein nonlinear system identification problem. The limitation of this approach is that the dimension of the resulting linear block system can be very large, and therefore, convergence or robustness of the algorithm becomes an issue [18]. Recently, Bai reported a blind approach to Hammerstein system identification using least mean square (LMS) algorithm [18]. The method reported applied a two-stage identification process (Linear Infinite Impulse Response (IIR) stage and the nonlinear stage) without any knowledge of the internal signals connecting both cascades in the Hammerstein system. This method requires a white input signal to guarantee the stability and convergence of the algorithm. Jeraj and Mathews derived an adaptive Hammerstein system identification algorithm by linearizing the system nonlinearity using a Gram-Schmidt orthogonalizer at the input to the linear subsystem (forming an MISO system) [17]. This method also suffers the same limitations as the block-based adaptive Hammerstein algorithms. Thus, to improve the speed of

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