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# ADAPTIVE CONTROL OF TIME-VARYING SYSTEMS WITH TIME-VARYING DELAYS

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**Abstract**. This paper deals with a robustly stable adaptive pole-placement- based controller for time-delay linear systems with possibly time-varying and unbounded point delays under unmodeled dynamics and bounded disturbances. Both the plant parameters and delays are allowed to be time-varying and differentiable with respect to time with bounded derivative. The mechanism used for robust adaptive stabilization consists of a relative dead zone which freezes the adaptation for small sizes of the adaptation error compared with the estimated size of the contribution of the uncertainties to the filtered output. The proposed estimation algorithm combines the use of that adaptation relative dead zone with a $\sigma$tmodification rule for updating the parameter estimates and with a modified updating rule which weights the classical least-squares type updating rule with the first and second powers of the covariance matrix as well as with the identity matrix. The dead zone adaptation mechanism prevents against potential instability caused by uncertainties, the modified updating rule guarantees positive definiteness of the covariance matrix for all time under appropriate initial conditions. Finally, the $\sigma$-modification rule prevents against potential divergence of the parameter estimates caused by the modified covariance updating rule. A variant of the $\sigma$- modification is proposed in order to improve the algorithm properties for the case when an absolute upper-bound for the plant parameters is known for all time.
**Keywords**. Adaptive control, Covariance updating rule, Robustness, Time-delay systems.

## 1 Introduction

Recent research in adaptive control has been devoted to robustness issues of continuous and discrete adaptive systems against unsuitable unmodeled dynamics and presence noise and to the relaxation of classical assumptions like the stability of the plant inverse and the knowledge of the sign of the high frequency gain (see, for instance, [1-10]). Extensive work has also been developed related to the relaxation of the requirement of input persistent excitation ( [1-3], [5-6], [13]) or the knowledge of an overbounding function of the absolute contribution of the unmodeled dynamics to the plant input, [10]. The above relaxed hypothesis have also been extended to hybrid dynamic systems which consist of coupled continuous and digital substates, [11]. In particular, the relaxation of the plant inverse stability assumption has been performed by either incorporating projection of the parameter estimates on