ADAPTIVE POLE PLACEMENT WITHOUT EXCITATION PROBING SIGNALS

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Abstract : This paper presents an indirect adaptive control scheme for linear systems which may possibly be non-minimum phase. The control scheme achieves asymptotical pole placement without either introducing persistent excitation probing signals into the systems or assuming any *a-priori* knowledge on the plant parameters. The system order is the only *a-priori* knowledge required on the plant. The adaptive control law is free from singularities in the sense that the estimated plant model is always controllable. The singularities are overcome by a suitable parameter estimates modification which is based upon standard Least Squares covariance matrix properties. The analysis of the stability and the global convergence of closed loop system is given in detail for both discrete-time and continuous-time systems.

Adaptive control of non-minimum phase systems has received a lot of attention in the last decade. Significant research efforts have been devoted to obtain adaptive control algorithms that converge globally. Stabilization of non-minimum phase plants using adaptive control methodology is widely recognized as a problem in its own right and also as an important preliminary step in achieving additional control objectives concerning specific desired performance indexes.

The crucial problem in adaptive control of non-minimum phase plants arises when the plant parameter estimates are such that they correspond to parameter values for which the plant is not controllable. Minimum phase systems with known high frequency gain sign can be adaptively controlled without any singularities as was shown in many literatures. Nevertheless, as soon as either of the two assumptions fails to hold, singularities may appear in the control law. There are basically two different approaches to circumvent the regions in the parameter space corresponding to uncontrollable models. One of them relies on excitation probing signals and the other is based on modification of the plant parameter estimates.

The techniques relying on excitation signals have been developed in the way that the singularities are avoided by securing the convergence of the parameter estimates to the true plant parameter values. Nevertheless, a drawback of these techniques is that the excitation signals introduced in the system should be large enough to predominate over the plant noise and this may not be feasible or desirable in some practical applications.

Instead of the above mentioned approach, our alternative not resorting to excitation signals is based on a suitable modification of the parameter estimates to put them away from the singular regions in the parameter space. This modification can not be arbitrary since we require the modified parameter estimares to inherit some useful properties of the original estimates. This approach to avoid singularities in adaptive pole placement of possibly non-minimum phase plants can be obtained by redressing the parameter estimates before using them to compute the control input. In this technique the parameter estimates are adjusted in such a way that the convergence properties of the current parameter estimates are preserved so that they produce controllable estimated plant descriptions. In other words, the problem is reformulated into the one of identifying the plant parameters by minimizing a performance index on the prediction error subject to the constrain that the estimates lie in a region in the parameter space corresponding to controllable plants. However, in order to obtain a robust adaptive pole placement algorithm, one has to make sure that the modified parameter estimates are faraway enough from the surfaces in the parameter space which correspond to the non-stabilizable plants. The contribution of the present paper is the solution to the long standing problem of adaptive pole placement of possibly non-minimum phase systems of arbitrary order without introducing excitation probing signals into the system. An explicit parameter estimates modification is proposed such that the determinant of the associated Sylvester resultant matrix is uniformly bounded away from zero. The proposed scheme requires neither the introduction of the excitation probing signals into the system nor the constrains on the plant parameters to belong to particular regions in the parameter space. The control scheme operates with only one identification algorithm and requires no *a-priori* knowledge other than the system order. Simple proofs of convergence are presented in detail for both the discrete-time and continuous-time cases. The result presented in this paper can be interpreted as a parameter estimation technique constrained to controllability requirements for application in adaptive control. Of course, the result can also be interpreted as a particular adjustable controller that stabilizes the system even when the parameter estimates lie in the singular region in the parameter space where pole-zero cancellations occur. The convergence analysis was carried out for pole placement but it can easily be used for other control strategies defined for specific desired performances. The proposed adaptive control scheme not only stabilizes the plant, as is the case for the so called universal controllers, it also insures that in the limit the closed loop poles converge to the desired values for any arbitrary reference input.