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OBSERVER METHODS IN SELF-TUNING CONTROL

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ABSTRACT

A state-space formulation of the self-tuning control problem has been recently used to develop new self-tuning control algorithms and to study existing ones developed using the polynomial representation. A number of state estimation techniques used in self-tuning control are examined using the above formulation and it is shown that only certain recent self-tuning methods [7,6] employ an optimal state estimator.

SUMMARY

Self-tuning theory is used in the control of systems the parameters of which can be unknown and may vary with respect to time. Much of the earlier work, e.g. Åström & Wittenmark (1973), Clarke & Gawthrop (1975), was developed using a representation involving polynomials in the backward shift (delay) operator; in the last few years, however, a state-space formulation has been introduced, Warwick (1981), Tsay and Shieh (1981), which has not only allowed for a wider choice of possible control actions, but has also provided an insight into the theory underlying the self-tuning methods developed using the polynomial description.

As, generally, only plant input and output measurements may be obtained at each sampling interval, the state vector, necessary in the state-space design philosophy, must be estimated so that it can be formed from a combination of the input and output regressive measurements, and the plant parameter estimates. This, however, leads to the possible use of one of a large number of observer schemes; the most popular self-tuners employ standard observer forms, as found in Kwakernaak & Sivan (1972), and the state estimator is generally obtained by considering the plant parameters to be known, the fact that they may well not have been identified being taken into account later.

It is shown here, that certain schemes, e.g. Warwick (1981) and Tsay and Shieh (1981), employ an observer which is optimal (the Kalman-Bucy equivalent) in the sense that it attempts to minimize the mean square error in state reconstruction. This observer also contains the noise coloring polynomial as a factor of its characteristic polynomial, thus enabling a reasonably simple study of both the stability and the reconstruction error properties of the observer to be carried out. One property is immediately apparent, however, namely, the fact that if the disturbance is white noise then the observer becomes a dead-beat observer.

The noise coloring polynomial appears in the characteristic polynomial of the observer in several other self-tuning controllers, e.g. in the state-space equivalent form of (see Lam 1980) Clarke & Gawthrop (1975) and Wellstead et al. (1979). However, due to the formulation of the estimator equation to include the present measured output, the observer must be regarded in this case as being non-optimal in the same sense as previously mentioned. The different estimates of the state vectors can, though, be

related via a simple theorem and hence by designing the control law on the certainty equivalence principle, the various controller actions decided upon in this case can be expressed in terms of the optimal state estimate by means of a straightforward modification.

Of the more recently developed self-tuning controllers, several are of interest: In Wellstead and Sanoff (1981), the observer polynomial is essentially specified by the designer, and does not necessarily coincide with the disturbance polynomial; the effect this has on the reconstruction error is discussed. The varying characteristic polynomial inherent when linear output feedback is employed in combination with state feedback, Warwick and Westcott (1982), is also discussed, as well as the use of a state vector constructed solely from regressive measured values, Hesketh (1982).

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