Some aspects of optimal active detector design

Ivo Punčochář and Miroslav Šimandl

Department of Cybernetics & Research Centre Data-Algorithms-Decision Making
University of West Bohemia in Pilsen, Univerzitní 8, 306 14 Plzeň, Czech Republic

Extended abstract

The paper deals with active change detection problem in linear stochastic discrete time systems. In contrast to standard change detection problem [1], the aim is to design an active detector, which generates an auxiliary input signal exciting the observed system and provides decisions about changes in this system. The idea of the auxiliary input signal has come from identification experiment design [2], where the properly designed input signal can lead to better estimates of the system parameters.

Known active change detection methods are based entirely on using multiple linear models for description of the observed system. The stochastic multiple linear models and the sequential probability ratio test (SPRT) are considered in [3, 4]. Firstly, only two models are considered and the SPRT is used to detect a change. The auxiliary input signal is designed to optimize a selected property of the SPRT, namely average sampling number (ASN) and probability of wrong decision. In case of more than two models the SPRT must be modified (extended SPRT) to accommodate such situation. The extended SPRT is not optimal and design of the auxiliary input signal is based on minimization of a weighted sum of the pairwise model performance indexes. The weights are given as belief that the system after change can be described by corresponding model. However, the resulting auxiliary input signal can increase probability of wrong decision.

Another approach to active change detection uses deterministic linear multiple model [5]. Disturbances are modelled as signals bounded in amplitude or energy. It is considered that the system behavior does not change during a wisely chosen test period. Then the valid model is determined using the membership approach and auxiliary input signal should be designed in such way that the decision can not be wrong. If such auxiliary input signal exist then the test based on membership approach provides exact information about current system behavior. Unfortunately, it is not possible to guarantee that the system behavior does not change during the test period.

The more general change detection formulation has been introduced in [4]. The active detector is designed by minimization of a criterion penalizing wrong decisions over finite detection horizon. However, this idea was not elaborated in all details. A similar idea was introduced in [6], where a special case of active detector was studied more deeply using three information processing strategies (IPS's), namely open loop, open loop feedback, and closed loop strategy. The solution obtained using these three IPS's were related to the standard solutions and the results were illustrated in a numerical example. Further extensions of this idea were proposed in [7, 8].

This paper presents some interesting aspects of active change detection problem solved in [7]. The active change detection problem is formulated and general solution, based on utilizing dynamic programming, is provided. Further, only two scalar Gaussian models are considered on two step detection horizon, because the general analysis is too difficult to perform. The influence of auxiliary

input signal on change detection is discussed for this simple case. The improvement of change detection depends on amplitude of the auxiliary input signal and on differences between corresponding parameters of the models. It is shown that some of parameter differences are important and if this differences are zero than the auxiliary input signal can not lead to better decisions.

In fact, the presented problem can be viewed as decision making under uncertainty, where the negative influence of the uncertainty is minimized using appropriate auxiliary input signal. The discussion provides better understanding of the active change detection problem and it shows key parameter differences, which determine the influence of the auxiliary input signal on the change detection.

References

[1] M. Basseville and I. V. Nikiforov, *Detection of abrupt changes – Theory and application.* New Jersey: Prentice Hall, 1993.

[2] L. Ljung, *System identification: Theory for the user.* London: Prentice Hall, 1987.

[3] X. J. Zhang, *Auxiliary Signal Design in Fault Detection and Diagnosis.* Heidelberg: Springer Verlag, November 1989.

[4] F. Kerestecioğlu, *Change Detection and Input Design in Dynamical Systems.* Taunton: Research Studies Press, 1993.

[5] R. Nikoukhah, "Guaranteed active failure detection and isolation for linear dynamical systems," *Automatica*, vol. 34, no. 11, pp. 1345–1358, November 1998.

[6] M. Šimandl and P. Herejt, "Information processing strategies and multiple model fault detection," in *Proceedings of the* 22^{th} *IASTED International Conference on Modelling, Identification and Control*, M. H. Hamza, Ed. Innsbruck, Austria: Acta Press, February 2003.

[7] M. Šimandl, I. Punčochář, and P. Herejt, "Optimal input and decision in multiple model fault detection," in *Preprints of the* 16^{th} *IFAC World Congress*, Prague, Czech Republic, July 2005.

[8] M. Šimandl, I. Punčochář, and J. Královec, "Rolling horizon for active fault detection," in *Preprints of the* 44^{th} *IEEE Conference on Decision and Control and European Control Conference ECC 2005*, Seville, Spain, December 2005.