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Finite Memory Observers for linear time-varying systems: Theory and diagnosis applications

Guillaume Graton[a,*], Frédéric Kratz[b], Jacques Fantini[c]

[a]*Ecole Centrale of Marseille and the Laboratory of Information Sciences and Systems, Ecole Centrale Marseille, Technopôle de Château-Gombert, 38 rue Frédéric Joliot Curie, F-13451 Marseille Cedex 20, France*
[b]*ENSI of Bourges and the PRISME Laboratory. ENSI de Bourges, 88 boulevard Lahitolle, F-18020 Bourges, France*
[c]*Polytech'Orléans, University of Orléans and the PRISME Laboratory. Polytech' Orléans - Site Léonard de Vinci, 12 rue de Blois, BP 6744, F-45067 Orléans, France*

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Abstract

Fault detection and diagnosis are important issues in process engineering. Hence, a considerable interest exists in this field now from industrial practitioners as well as academic researchers, as opposed to 30 years ago. The literature on process fault diagnosis, ranging from analytical methods to artificial intelligence and statistical approaches, is largely widespread. In this paper, the modeling of the real process is known, and the state-space representation is used. The properties of the Finite Memory Observer (FMO) are studied from a global point of view for the class of linear time-varying (LTV) systems with stochastic noises. The FMO performances are framed by the study of their properties, and that of their influences on diagnosis results. Fundamentally, the generation of residuals is an essential procedure in diagnosis. So, the determination of the optimal window length of the observer is resolved, and the generation of residuals for diagnosis completed. In the first part, the design of the observer and the residual generation are shown. The second part is devoted to the study of the sensitivity and robustness of the observer and of residuals generated from the observer.

1. Introduction

The increase in and the complexities of new technologies make diagnosis studies more and more prevalent within the automatic control community. The role of diagnosis is increased in

*Corresponding author. Tel.: +33 491 05 46 11.
E-mail addresses: guillaume.graton@centrale-marseille.fr (G. Graton), frederic.kratz@ensi-bourges.fr (F. Kratz), jacques.fantini@univ-orleans.fr (J. Fantini).

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Nomenclature

$\mathcal{V}$	measurement noise vector for the window length L_S
$\mathcal{W}$	state noise vector for the window length L_S
$\Omega_L^{-1}(k)$	variance of the estimation error
$\varepsilon(k)$	estimation error
A_k	state matrix
B_k	control matrix
C_k	measurement matrix
L_S	size of the observations window defined by $L_S = L + 1 - S$
$r(k)$	state estimation residual vector
$R_L(k)$	covariance matrix of the observer noise
$r_y(k)$	measurement estimation residual vector
U	control vector for the window length L_S
$u(k)$	control vector
$v(k)$	measurement noise vector
$V_L(k)$	covariance matrix of the measurement noise
$w(k)$	state noise vector
$W_L(k)$	covariance matrix of the state noise
$x(k)$	state vector
Y	measurement vector for the window length L_S
$y(k)$	measurement vector

industrial systems to ensure good process reliability. Technical evolution of high technologies based on electronic systems contributes to the diagnosis extension of diagnoses with the addition of new components such as sensors and actuators. Having said that, new configurations imply new problems and this sophistication could lead to the appearance of new faults. Nowadays, the main strategies in diagnosis and automatic control are to propose new tools providing more safety for diagnosis or from a wider perspective to provide accurate control for the processes studied.

Diagnosis plays a great part in system monitoring and in industrial processes, especially when risks concerning safety are involved. Diagnosis procedures must provide for accurate detection of faults which are responsible for breakdowns, accidents, production stoppages, etc. Breakdowns are undesired in industrial processes but also in everyday life. Breakdowns are a sign of bad quality. Fault detection before a breakdown is thus of primary importance if the system is to be stopped before ruptures or catastrophes occur.

A great number of articles deal with diagnosis applications from various aspects: the scheme of Chow-Willsky [1], relations of parity [2,3], fault detection using observers [4], can be quoted; but also, with a different approach, statistical methods such as [5,6].

In this paper, as the modeling of the system is supposed known, a model-based diagnosis can be applied, and more particularly the concept of observers can be precisely implemented to compare measurements and their estimations. Nevertheless, the accumulation of model uncertainties leads to the non-convergence to zero of the state estimation error (the residual) that cause the robustness degree of the detection system to decrease. Such a phenomenon was studied by Toda et al. [7] for Luenberger observers and by Heffes [8] for Kalman filters.