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Supervisão e Controlo de Sistemas Dinâmicos com Tolerância a Falhas – Contribuição para uma abordagem estruturada e robusta

Supervision and Fault-Tolerant Control of Dynamical Systems – Contribution for a structured and robust approach

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Abstract of the PhD Thesis

The main purposes of the work presented in this Thesis are the development of a model based Fault-Tolerant Control System (FTCS) for dynamical processes and its implementation on nonlinear laboratory processes, representative of systems of higher dimension and complexity, integrated in industrial process, environmental protection systems or in medical equipments.

This work aims to give a contribution for a structured formulation of a fault-tolerant control system, including the design of a fault detection and diagnosis module, a robust controller with passive fault tolerance, a control reconfiguration module with active fault tolerance and a supervisor module.

The fault tolerant supervisory control systems are feedback control systems with the property of tolerance to faults, or even failures, in sensors, actuators or process components, assuring fundamentally the system stability and a certain performance degree, showing possibly some performance degradation within acceptable limits. These systems are usually classified as passives or actives. In the former case, the control system is designed in order to attenuate the effects of faults with small magnitude and without an evolution to a failure of the component. In active systems, the supervisory system makes use of the information from the fault diagnosis module to activate the fault accommodation mechanisms, to reconfigure the system or even to switch off the process, depending on the fault severity.

The proposed approach considers a nonlinear global model to describe the process dynamics and the design of the supervisory control system based linear models with uncertainty describing the errors of modelization and linearization around one or more nominal operation modes. These operation modes may result from significantly nonlinear process' characteristics and/or from operation modes in faulty cases.

In the passive case, a model-based approach is used to estimate the system's outputs and to synthesise the robust controller. The design objectives and the system's uncertainties are formulated in terms of H_∞ specifications and the problem is solved using the structured singular value, μ.

In the active case, the fault tolerant control system uses a supervisor subsystem to select the suitable actions in order to preserve the system's stability and performance and to assure fault tolerance for the closed loop system. The proposed approach considers a fuzzy-logic implementation to handle the information received from the process, the fault diagnosis subsystem and from the human supervisor. The system includes another subsystem for fault identification based on residuals generated by the fault detection and isolation module. An executor is considered to carry out the remedial actions in order to achieve fault accommodation. The supervisor exploits also the physical and analytical redundancies to reconfigure the control system whenever severe faults are identified, using virtual sensors and virtual actuators. Concerning the control system, it is defined by a set of controllers designed for each operation mode. One of the supervisor's tasks is to identify the operation mode and to select the suitable controller, accordingly.

The results obtained with the application of the proposed passive and active approaches in nonlinear real processes (the Inverted Pendulum apparatus, the Distributed Solar Collector (DSC) field of the Plataforma Solar de Almería and the Three-Tank benchmark plant) give good perspectives for its usability in more complex plants.

Keywords: Dynamical systems, uncertain linear models, Fault Detection and Isolation (FDI), Fault Tolerant Control (FTC), robust control, switching control, fault accommodation, system reconfiguration.