Chapter 13
Design of Robust Approach for Failure Detection in Dynamic Control Systems

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ABSTRACT

This paper presents a robust instrument fault detection (IFD) scheme based on modified immune mechanism based evolutionary algorithm (MIMEA) that determines on line the optimal control actions, detects faults quickly in the control process, and reconfigures the controller structure. To ensure the capability of the proposed MIMEA, repeating cycles of crossover, mutation, and clonally selection are included through the sampling time. This increases the ability of the proposed algorithm to reach the global optimum performance and optimize the controller parameters through a few generations. A fault diagnosis logic system is created based on the proposed algorithm, nonlinear decision functions, and its derivatives with respect to time. Threshold limits are implied to improve the system dynamics and sensitivity of the IFD scheme to the faults. The proposed algorithm is able to reconfigure the control law safely in all the situations. The presented false alarm rates are also clearly indicated. To illustrate the performance of the proposed MIMEA, it is applied successfully to tune and optimize the controller parameters of the nonlinear nuclear power reactor such that a robust behavior is obtained. Simulation results show the effectiveness of the proposed IFD scheme based MIMEA in detecting and isolating the dynamic system faults.

INTRODUCTION

The application of modern control theories plays an important role for the improvement of the dynamic performance and safety of nuclear reactors (Subramaniam & Rajakumar, 1995). The model equations of the nuclear reactor are nonlinear. Conventional PI controllers may require several tuning adjustments to get satisfactory performance. Nonlinear control strategy is a must for the control of nuclear reactors. Input-output linearizing controller for a nuclear reactor is designed

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which shows that the performance of the closed loop system is good. However, it has not evaluated the robustness of both system parameters perturbations and component failure detection (Guimara & Lapa, 2004, 2005). The operation of any industrial plant is based on the readings of a set of sensors. The ability to identify the state of operation, or the events that are occurring, from the time evolution of these readings is essential for the satisfactory execution of the appropriate control actions. In supervisory control, detection and diagnosis of faults, adaptive control, process quality control, recovery from operational deviations, and determining the correct mapping from process trends to overcome some problems of operational conditions are the pivotal task of (Roverso, 2000).

Control systems are becoming more and more powerful and sophisticated. Reliability, availability, and safety are primary goals in the operation of the process systems (Odgaard & Thøgersen, 2010). The aim is to develop a fast and reliable control system that could detect undesirable changes in the process (referred to as "faults") and isolate the impact of faults has been attracting much attention of researchers. Various methods for fault detection and control of process systems have been studied and developed over recent years (Staroswiecki, 2005; Zhang & Jiang, 2003; Ducard & Geering, 2008; Li & Parker, 2007) but there are relatively few successful developments of controller systems that can deal with faults in stochastic hybrid sense where faults are modeled as multiple-model set with variable structure and use of a stochastic model predictive control algorithm. Faults are difficult to foresee and prevent. Traditionally, faults were handled by describing the result behavior of the system and were grouped into a hierarchical structure of fault model (Li & Parker, 2007). This approach is still used for some fields in practice. When a failure occurs, the system behavior changes and should be described by a different mode from the one that corresponds to the normal mode. A more appropriate mathematical model for such a system is the so-called stochastic hybrid approach. It differs from the conventional hierarchical structure in that its state may jump as well as it may vary continuously. Apart from the applications to problems involving failures, hybrid systems have found some success in such areas as target tracking and control that involve possible structure changes (Zhang & Campillo, 2005). For detecting the faults, a critical assumption, in the simulation test runs, which is the availability of the system component models under different input excitations. Such models may not be available for the necessary input conditions in an operating system (Sarkar & Yasar, 2008; Gupta & Ray, 2008).

Artificial immune systems constitute intelligent methodologies that can be used to churn out effective solutions to real world problems. Inspired by the natural immune system, an artificial immune system banks on concepts derived from theoretical immunology and observed immune functions to solve a problem. The body's defense mechanism can be divided into two sub-systems: (i) the innate immune system, and (ii) the adaptive immune system. The former is available for immediate combat while the latter produces antibodies depending on the invading agent. The skin and the lining of the body cavities that are open to the outside world provide the initial protective barrier. A virus or bacteria (generically known as a germ) may invade the human body and reproduce. The germ's presence produces some side effects, like fever, inflammation, etc. Some bacteria on the contrary are benign. In immune system terminology, the invading agent is called the antigen while the defending agent is termed the antibody (Wang & Hirsbrunner, 2003). The vertebrate immune system is a rich source of theories and acts as an inspiration for computer-based solutions over the last few years there has been an increasing interest in the area of artificial immune system. Artificial immune systems uses ideas gleaned from immunology in order to develop systems capable of performing tasks in various engineering