Chapter 14
Fault Detection, Isolation and Characterisation for Discrete Event Systems Based on Petri Nets Models

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ABSTRACT

Petri net models are used to detect and isolate faults in case of discrete event systems as manufacturing, robotic, communication and transportation systems. This chapter addresses two problems. The first one is the structure designs and parameters identification of the Petri net models according to the observation and analysis of the sequences of events that are collected. Deterministic and stochastic time Petri nets are concerned. The proposed method is based on a statistical analysis of data and has a practical interest as long as sequences of events are already saved by supervision systems. The second problem concerns the use of the resulting Petri net models to detect, isolate and characterize faults in discrete event systems. This contribution includes the characterization of intermittent faults. This issue is important because faults are often progressive from intermittent to definitive and early faults detection and isolation improve productivity and save money and resources.

INTRODUCTION

One of the most challenging issues for engineers and researchers is to develop machines and systems that are able to operate reliably in varying conditions and that are equipped with self-diagnosis capabili-

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ties and autonomous adaptation in order to increase productivity and to improve working conditions and safety in industrial environments (Rausand & Hoyland, 2004). But modern technological processes include complex and large scale systems, where faults in a single component have major effects on the availability and performances of the system as a whole. For example manufacturing systems consist of many different machines, robots, communication and transportation tools all of which have to correctly satisfy their purpose in order to ensure and fulfil global objectives. In this context, a fault is any event that changes the behaviour of the system such that it does no longer satisfy its purpose. Faults affect the system (they change the dynamical input – output properties), the sensors (they result in substantial errors during sensors reading), or the actuators (they disturb the influence of the controller to the plant).

In order to limit their effects on the system, fault detection and isolation methods (FDI) are developed (Blanke et al., 2003). Fault detection decides whether or not a fault has occurred. This stage also concerns the determination of the time at which the fault occurs. Then, fault isolation finds the component that is faulty. FDI may also be improved with a complete fault identification and characterisation that will give useful information about the fault (and eventually recovery) processes. This stage is of particular interest in case of intermittent faults that drive the process from a normal state to a faulty one and then from the faulty state to a normal one several times-(Contant et al., 2002). FDI methods are usually separated into model-based and data-based approaches. Data-based approaches are preferred when no model is available and model-based approaches are discussed according to the model type used: architectural and structure graph models for qualitative reasoning (Blanke, 1996), differential or difference equations and transfer functions for continuous systems (Patton et al., 1989, 1999; Gertler, 1998), automata or Petri nets for discrete event systems (DESs) (Blanke et al., 2003).

This chapter concerns model-based FDI methods for DESs. The main contributions are to provide a systematic method for the design and identification of Petri nets (PNs) according to the collected event sequences and then to use the resulting models for FDI issues. The next section introduces some FDI and diagnosis methods for DESs. It focuses on PNs-based methods and points out the necessity to design reference and faulty models in a systematic way. The third section is about the design and identification of PNs. PNs are introduced, then the design of state graphs is detailed and the identification of the parameters that characterize the firing periods is described. Deterministic and stochastic PNs are obtained according to the statistical analysis of events that are collected into the observed sequences. The section four concerns the use of the reference models for FDI issues. It also introduces the characterisation of faults that improves the understanding of the fault and recovery processes that affect industrial systems. Examples are detailed to illustrate the theoretical results.

BACKRGOUND

DESs are characterized by signals that switch from one value to another one rather than changing their value continuously. DESs occur naturally in the engineering practice. Many actuators like switches, valves and so on, only jump between discrete states. Domains of application include communication networks and protocols, industrial process, production and transportation systems, electrical engineering, and robotics. Binary signals are mainly used with numerical systems and logical values "true" and "false" are used as input and output signals. Moreover, in several systems also the internal state is discrete valued. As an example, robot encoders are discrete valued even if the number of discrete states is large enough to produce smooth trajectories. In the context of FDI and diagnosis, DESs occur also

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