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A formal framework for the decentralised diagnosis of large scale discrete event systems and its application to telecommunication networks

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Abstract

We address the problem of diagnosing large discrete event systems. Given a flow of observations from the system, the goal is to explain these observations on-line by identifying and localising possible failures and their consequences across the system. Model-based diagnosis approaches deal with this problem but, apart very recent proposals, either they require the computation of a global model of the system which is not possible with large discrete event systems, or they cannot perform on-line diagnosis. The contribution of this paper is the description and the implementation of a formal framework for the on-line decentralised diagnosis of such systems, framework which is based on the "divide and conquer" principle and does not require the global model computation. This paper finally describes the use of this framework in the monitoring of a real telecommunication network.

Keywords: Model-based diagnosis; Discrete event systems; Decentralised model; Distributed artificial intelligence; Telecommunication networks; Fault propagation

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1. Introduction

The problem we deal with is the supervision of complex and large discrete event systems such as telecommunication networks, electricity distribution network, and more generally speaking *Immobots* [29]. Given a supervision system continuously receiving observations (alarms) sent by the system components, our purpose is to help operators to identify failures. Two classical approaches in monitoring such systems are knowledge-based techniques that directly associate a diagnosis to a set of symptoms, for example expert systems [17], or chronicle recognition systems [7,9], and model-based techniques which rely on a behavioural model of the system [22]. The main weakness of the first approach is the lack of genericity: as the system changes (new components, new connections, new technologies), a new expertise has to be acquired. Therefore, we focus on model-based techniques which are known to be better suited to that kind of system than expertise-based approaches.

A number of model-based approaches for diagnosing discrete event systems have been proposed in both the AI and control engineering literature. They cover continuous-variable systems which, after quantisation, are represented as discrete systems [15], as well as "discrete by nature" systems such as communicating processes which exchange messages and alarms. The majority of these approaches are centralised approaches [15,23,26]. For instance, the diagnoser approach [26] consists in the compilation of diagnostic information in a data structure (called *diagnoser*), which maps observations to failures for on-line diagnosis. The main drawback of centralised approaches is that they require to explicitly build the global model of the system which is unrealistic for large, complex systems such as telecommunication networks.

The considered systems are naturally distributed so it is easier to model those systems in a decentralised way. An approach for diagnosing discrete event systems using decentralised diagnosers can be found in [8], but the computation of each decentralised diagnoser is still based on a global model. There also exist methods relying on a decentralised model [2,6], but these are used *off-line* to solve a diagnosis problem *a posteriori*. Recently, due to the need of solving a diagnosis problem on-line, a monitoring-based approach [13,14] has been developed: this method mixes a diagnoser approach [26] with an extended version of the decentralised model of [2] by computing on-line only the interesting parts of a centralised diagnoser without computing a global model. This method still has the problem that it systematically uses global states of the system which can be a problem when dealing with large discrete event systems.

In this paper, we propose a formal framework providing an approach which relies on a decentralised model and computes on-line diagnosis of large discrete event systems. Firstly, we propose a formalism for decentralised models based on communicating automata. This formalism allows us to model behaviours of large discrete event systems in a modular way and to use decentralised algorithms on it thanks to a generic synchronisation operation.

Secondly, we define the diagnosis problem inside this framework and propose an algorithm to make on-line diagnosis. To make an on-line diagnosis system, efficiency is the key issue. The idea is to split the flow of observations into temporal windows. For each temporal window, we compute a diagnosis for a subsystem (*subsystem diagnosis*) and then