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Monitoring and predictive maintenance: Modeling and analyse of fault latency

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Abstract

This paper presents an effective way of modeling complex systems through identified functioning modes. In the proposed approach, the integration of monitoring in the manufacturing system is facilitated by the development of a generic model. The aim is to propose a monitoring system able of absorbing internal degradation of any variables and ensuring the continuity of the service. The outline of the optimization of the fault latency method is based on two steps is proposed. The first step is the evaluation of fault latency and the second one is the performance evaluation of monitoring process. Timed automata are the modeling tool used for these two steps. The proposed method can be applied to various kinds of processes and gives good results. Indeed, the simulation results, including a serial manufacturing line, substantiate the feasibility of the proposed method and provide a promising potential to spin-off applications in industrial manufacturing system.

Keywords: Discrete–event systems; Detection; Fault latency; Predictive maintenance; Timed automata

1. Introduction

In manufacturing systems, wear-out and eventual failures are unavoidable. However, to reduce the rate of their occurrences and to improve the lifetime of equipments, maintenance can be performed with an adequate monitoring. In fact, monitoring in production systems may alert the maintenance team when a given degradation increases above a specified threshold [1,2,3,20]. This allows a solution to be found before the occurrence of the failure.

Modern industry deals with efficient monitoring to improve reliability of equipment and reduce high maintenance cost [5,16]. Now, the mission allowed to the monitoring system is not only the detection task but also the identification of fault. To detect and identify any faults occurring in the dynamical system, it is necessary to find the kind location, and a time of fault occurrence [1,5].

In discrete–event systems area, the most common monitoring and diagnostic approach are based on dynamic model, which represents only the good functioning. The inputs and outputs of the system under supervision are used to detect the fault [4,9,15]. Model-based diagnostic algorithms use an explicit model of dynamical system under investigation. This model incorporates the knowledge about the faultless and the faulty system behaviour in systematic way for the analysis of the fault symptoms [7,8].

For large manufacturing systems, monitoring integration requires specific developments due to the complexity of the models involved [3–5]. Furthermore, these developments consume large computing time resources.

Recently, process monitoring and diagnostic methods have been developed for discrete–event systems by using timed Petri nets, stochastic automata, timed automata, template languages or Semi-Markov processes [10,12,14,18]. The main idea of these methods is to simulate nominal or faulty system behaviour with the discrete model. These methods need the structural and functional models of the system. The faulty behaviour is modelled by using a predefined list of eventual faults which can affect the system.

The proposed monitoring function for predictive maintenance is a part of global system supervision. Thanks to the

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available data about the functioning mode of the system, the aim is to detect, localize and diagnose all the wear-out that can affect performance dependability of the system. The monitoring function increases the availability of the system. Indeed, the early fault detection and localization minimizes unavailability of equipment [13,19]. The aim is to propose a monitoring system able of absorbing internal degradation of any variables and ensuring the continuity of the service.

This paper proposes a new approach based on the control of tasks duration. This method is based on temporal measure, like the end of the task execution. Three functioning modes are defined. The system is in the normal mode for faultless functioning, the degraded mode for functioning, where the temporal measures are in the acceptable margins and the failure mode when the defined tolerance margin is exceeded. The proposed approach reduces the complexity of the model. It is applied to particular equipments in manufacturing system like conveyer, paint station, packaging station... where the time to achieve a task is an significant parameter. For other kind of degradation like the effect of vibration or temperature, it is necessary to use other complementary tools [5,6,16,17].

This paper presents an effective way of modeling complex systems through identified functioning modes. In the proposed approach, the integration of monitoring in the manufacturing system is facilitated by the development of a defined generic mode.

The outline of the optimization of the fault latency method is also developed in the paper. For the manufacturing systems, the aim is to evaluate at first how many time the systems can stay in the degraded state (fault latency). Then, for this optimal time the second goal is to evaluate the performance of the proposed monitoring model in terms of fault coverage. The general principle of the method is described with the used tool: the timed automata.

In this paper, we focus on these four steps:

- identification of generic modes,
- modeling by timed automata,
- evaluation of fault latency,
- fault coverage and performance evaluation of monitoring process.

This method is applied to a class of manufacturing systems: the serial line.

2. Principle of the method

The monitoring system is based on the control of tasks duration. An advantage of this method is that the detailed list of failure modes is not required anymore. Thus, a detailed analysis of the system is not needed; which leads to a simpler implementation. The proposed approach can also take into account the degraded functioning mode of the system [1,8,13]. The principle of the method is illustrated by Fig. 1.

For each task, applied simultaneously to the process and behavioural model, an event which means the end of the execution task is provided. An event must appear at the time T_n (time task duration) as foregone in the monitoring model. The detection is based on the comparison of this time with the real time needed by the process to execute the task denoted by T_r.

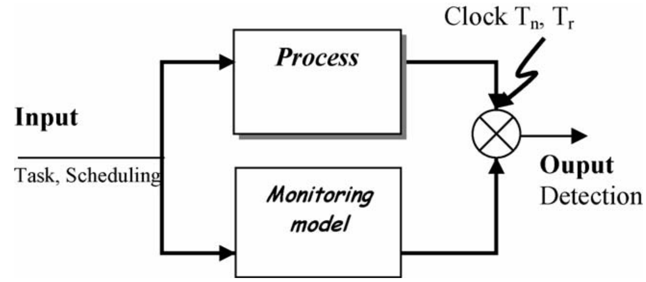

Fig. 1. Principle of the approach.

From a scheduling tasks, monitoring consist to follow the dynamic evolution of the system. The first step in the monitoring is to choose the pertinent parameters to follow which depends on the application.

3. Identification of generic modes

When all tasks of the process are executed in a predefined interval δ, the system is in a good functioning mode. If the task duration exceeds this interval, the system become in degraded mode during one defined tolerance interval. If the system remains in this state out off this tolerance interval, one considers the system is in failed mode. Then, the monitored system must take into account these three states. As long as the tasks duration falls in interval δ, the process is in a good functioning state. When the task duration exceeds δ, the process switches to the degraded functioning state as shown in Fig. 2. It stays in this state until an additional tolerance interval is exceeded. This situation depend on a defined the tolerance interval Δ named fault latency [19]. Then, if this interval is exceeded, the process falls in the failure state.

Three functioning modes can describe all processes: normal, degraded and failed state [13]. The system will oscillate between the normal and degraded functioning until a failure occurs in which case the system switches in the failed state. From a modeling point of view, the normal and degraded states are similar (same structure), their associated sub states and transitions are isomorphic. The difference between these modes is only the tolerance associated to the according task duration. The failure state is an absorbing state, which need maintenance intervention.

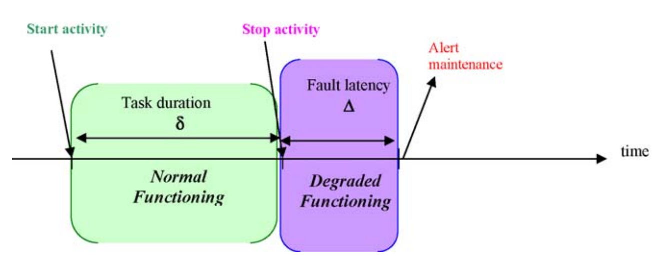

Fig. 2. Evolution of functioning mode.