Nonlinear Analysis: Hybrid Systems 4 (2010) 766–774

Contents lists available at ScienceDirect

Nonlinear Analysis: Hybrid Systems

journal homepage: www.elsevier.com/locate/nahs

Monitoring of dynamic processes by rectangular hybrid automata

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ARTICLE INFO

Article history:
Received 28 April 2010
Accepted 4 May 2010

Keywords:
Monitoring
Rectangular hybrid automats
Dynamic processes
Reachability analysis

ABSTRACT

In this paper we develop a method of monitoring dynamic processes based on rectangular hybrid automats. This method takes into account the behavior of the system and the evolution of its parameters. A failure during the execution of the process can lead to a dysfunctional state in the system.

The monitoring system, we propose, makes it possible to detect this state of dysfunction as soon as possible thanks to the reachability analysis.

1. Introduction

The current economic context has made the requirements of performance, reliability, and security of the real systems essential. Considering the growing complexity of these systems, it is necessary to establish a monitoring mechanism that can detect the dysfunction of the system.

There are two monitoring methods: the method without model and the method based on a model. The first one uses only heuristic knowledge on the system; we shall mention the methods based on expert systems [1], or neurones' networks [2]. Based on qualitative models, the second one makes it possible to represent the behavior of the process with a certain degree of abstraction, through models that are no longer mathematic but of a symbolic order. In order to have the monitoring system able to detect the deviations of normal functioning, the qualitative models have to represent systems that are qualitatively continuous [3], discrete and hybrid [4,5]. We consider a normal functioning of a system, any functioning of the latter that does not lead to a faulty state.

The purpose of a monitoring system used on an industrial process, is to emit an alarm by analyzing the information sent out by the captors or signals coming from the command process (Fig. 1). The issue of the monitoring of industrial systems has been dealt with in several works; both on the continuous systems [6] and on the systems with discrete event and hybrid systems [3]. Very few works, however, are to be found on dynamic hybrid systems.

The major issue we are concerned with here consists in studying a system in real time that is able to develop in several different functioning processes. Each of these processes having a distinct evolution dynamics. A system's dynamics can be represented in various ways. The more complex dynamics are, the weaker the possibilities of formal analysis.

As far as we are concerned, we are considering a factual vision in which we inject a continuous behavior. In the first works that have already been done [7], the dynamics are given by clocks that can be stopped. It became then possible to synthesize a monitoring system for processes that can be interrupted. This monitoring is done as soon as possible through the construction of the exact space that can be accessed. We are considering here models of hybrid dynamics in which the

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1751-570X/$ – see front matter
doi:10.1016/j.nahs.2010.05.004

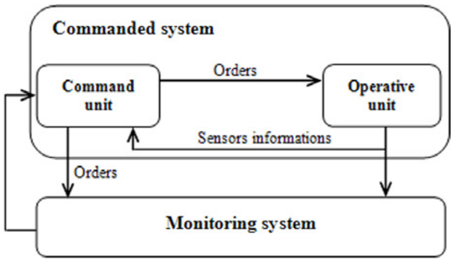

Fig. 1. Commanded system of monitoring model.

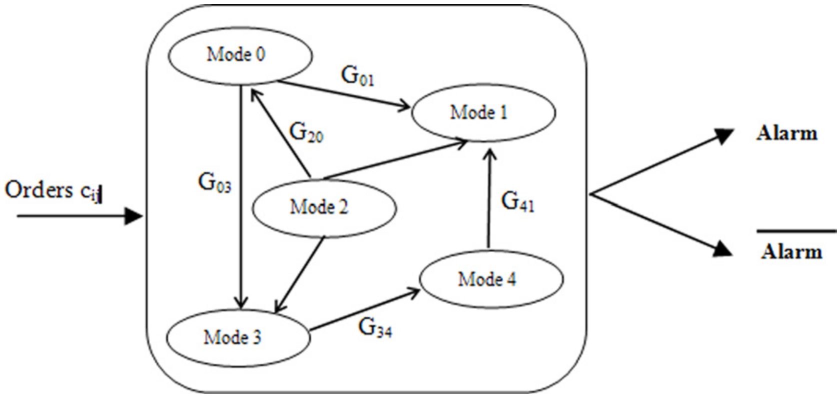

Fig. 2. Model of surveillance of the commanded system.

dynamics of the continuous part is given by equations of dx/dt= constant type. That will make it possible to increase the class of the systems studied. Monitoring consists then in guaranteeing at every moment the system will be operational while respecting both physical and specification constraints. The fact of having dynamics that go beyond the clock will make it possible to model in a finer way the physical constraints of the system.

The modelling tool chosen is the rectangular hybrid automated model (*RHA*) because it presents a rich hybrid modelling and allows a formal analysis. We are proposing to determine a rectangular hybrid automated model characterizing the normal functioning of the system. The system will develop in several functioning modes from the orders received by the command unit, the transition between these modes being managed by guards depending on the C_{ij} commands (Fig. 2). It is important to monitor the system's actions through the observation performance of the command actions. A monitoring system is efficient if it can anticipate malfunctioning, it is what is called detection at the earliest time. In a case of alarm activation, the monitoring system indicates to the command system that it is necessary to recalculate another command sequence (Fig. 1). The classical follow-up techniques of discrete event system consist in waiting for the maturity date of one or several temporizations, corresponding to the characterization of the space of the trajectories that can be reached through a hypercube and constitute a rough approximation. In our works knowing the *RHA* reachable space will allow to determine the exact dynamic trajectories and to detect the dysfunction of the system as soon as possible.

2. Intuitive presentation of the approach

In order to illustrate the problem well, we are considering the following system (Fig. 3). A gluing workshop including a P1 post, in which there is a deposit of glue on the workpiece. A conveyor will carry this workpiece toward P2 post where the gluing operation will take place. The conveyor begins his task following the conveyor's start '***ST***' order (once the glue has been deposited on the workpiece). The End, '***Ed***' event takes place when the workpiece reaches the P2 post. The conveyor belt has two functions: the first one is to carry the piece from P1 to P2 and the second is that it is used as a delaying device. Indeed, the piece's path is determined so that the glue is ready for use. The conveyor has a V_0 nominal speed, corresponding to a transport time of 8 t.u. (Time Units). The glue is exploitable during the [8,4] t.u. interval.

The monitoring model of the example illustrated by Fig. 3, is built in order to present our approach. As soon the controller gives the Start '***St***' order, two variables x and y are initialized (Fig. 4). The x variable measures the time gone by since the start up of the conveyor until it stops, x's dynamics value will be the following: $\dot{x} = 1$; the conveyor is in action.

y variable indicates the piece's position on the conveyor, the length of the path is 16 m. y's dynamics can take several values, it belongs to the {0, 1, 2, 3} set; we will have thus 4 functioning modes of the system.

Remark. This approach uses a sub-class of rectangular hybrid automats, the linear hybrid automats.