

Indirect monitoring of the failures of a flexible manufacturing system under cyclic scheduling

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Abstract

We are interested in flexible manufacturing systems and more particularly in their well functioning. In such a context, we opted for a deterministic and cyclic command, which optimizes several criteria such as Work in Process and workflow. In order to supervise the system functioning, we propose to survey the system output and compare it to the deterministic schedule. We will give a diagnostic principle to identify the root cause of the detected symptoms.

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1. Introduction

In control architecture of an APS (automated system of production), the monitoring aims to identify the state of the system at any moment. It is an informational function (within the meaning of model OI—operative, information, decision— [LEM90]) which supplies data decisional modules within the functions of supervision and maintenance. Classically, the monitoring consists of two distinct tasks: detection and diagnosis. The role of detection is to determine any failure of the supervised system. Normally, the failures can be localized as well within the command or the operative part. In this paper, we will focus on the monitoring of failures of the operative part. Our approach of detection consists of making sure that the system evolves in accordance with the expected behavior specified by its designer. Any variation compared to the awaited behavior is interpreted as the proof of an abnormal operation. From a practical point of view, the role of detection is to determine these variations and to communicate them to diagnosis. The function of diagnosis is to analyze these

variations in order to identify their causes. The causes are then communicated to the decision functions of the supervision and maintenance, which decide the procedure of recovery to set up taking into account dependability goals.

This general outline of survey/reaction depends on the techniques of monitoring used. We can classify these techniques in two families called direct and indirect.

A technique of monitoring is called direct if it is based on monitoring sensors. It requires a specific instrumentation of the plant so as to allow detection and the diagnosis. At the opposite, the indirect techniques exploit “logical” sensors. These logical sensors are designed from algorithms of data fusion or events correlation ([1,2]). The principal advantage of the direct techniques is that they generate a strong reactivity. On the other hand, the use of a great number of additional sensors of monitoring decreases clearly the reliability of the system. This justifies the interest of indirect approaches.

In [3], we proposed an approach of indirect monitoring based on the analysis of workflows in a reactive control context. Although innovating on many aspects, the suggested approach has several limits, in particular, from the reactivity point of view. Indeed, the necessary periodicity to obtain a cyclic behavior was quite large

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(several hundreds of units of time). Hence, it seems more natural to consider a cyclic schedule of the machines to adopt this type of monitoring by workflow.

Cyclic scheduling is, by definition, deterministic. The breakdowns of the machines are supposed rare. So, it supposes that there are sufficiently large intervals during which the estimated control could be fully exploited without interruption. From this assumption raises the possibility of reaching the expected optimal performances and maintaining them over a sufficiently long time. Deterministic assumption can seem to be constraining, but it allows optimizing the flow of production and to control the production constantly by a precise knowledge of the system state. This assumption consolidates us more with our aim of supervising the system in order to be able to detect the possible variations of flow. Thus, we can hope to observe the system once per cycle and to be able to detect problems.

This paper is divided into two main sections. In the first section, we recall the properties of cyclic scheduling. We also introduce an example which will be used to illustrate our proposals. In the second section, we present our monitoring technique. Initially, we define the precise context of our study, starting from some working hypotheses that we justify. Then, we propose solutions to implement the detection and the diagnosis of the failures occurring in the plant.

2. Cyclic scheduling

2.1. Introduction

Cyclic scheduling is known to be adapted to the productions of big demand [4–6]. Indeed, these methods constitute a good approach to avoid the combinatorial complexity explosion due to the scheduling of all the operations while concentrating on the determination and the optimization of a repetitive frame (cycle). Recent works showed that they are also well adapted to small and medium demand by studying and optimizing associated transient states [6]. Among these methods, we can quote the critical machine scheduling [7], K-cyclic scheduling [8] and 1-cyclic scheduling [4,9,10]; these approaches aim to respect the optimal cycle time while minimizing the work in process (WIP). The 1-cyclic schedules are characterized by the fact that each machine does the same operations at the same dates in each cycle. In this paper we will focus on this scheduling type. In a pedagogic purpose of clarity, we will disregard transfer operations.

2.2. Illustrative example

In order to illustrate our approach, we introduce an example from the literature (see [9,10]). Three machines

$\{M_i/i \in \{1, \dots, 3\}\}$ compose the plant and allow making 2 types of parts T1 and T2. Each part is characterized by its operating sequence. An operating sequence is defined here by the sequence of operations and their respective duration (given in generic time unit or t.u. hereafter) on each machine.

T1: OP₁₁ (M₃, 2 t.u.), OP₁₂ (M₁, 3 t.u.), OP₁₃ (M₂, 2 t.u.);
 T2: OP₂₁ (M₁, 1 t.u.), OP₂₂ (M₃, 2 t.u.).

The cyclic production consists in producing, each cycle, three parts of T1 and two of T2. Hence, five parts are produced per cycle (see Fig. 1). Even if the three parts of T1 are identical, it is necessary to identify them and to distinguish them. Indeed, since each part has a different output date, it is necessary to know which part leaves the production system.

The cyclic schedule gives the result of Fig. 2: the optimal cycle time is equal to 11 time units and the bottleneck machine (slowest machine: working 100% of time) is M₁. The WIP used is optimal and equal to 5 (1 work-in-process by each part to be manufactured).

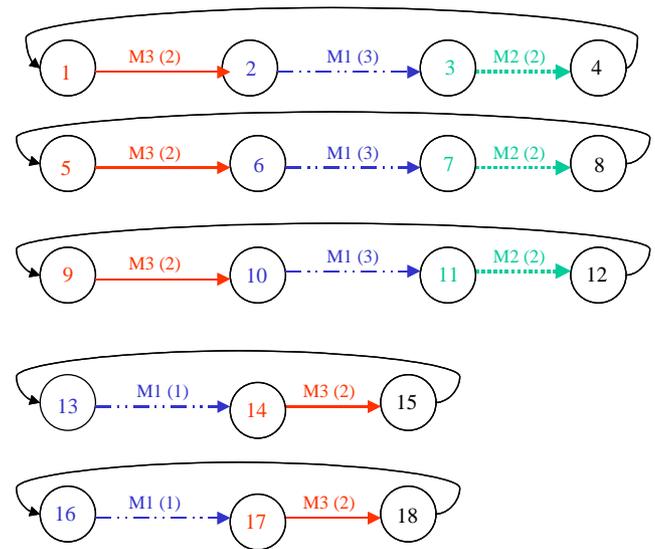


Fig. 1. Operation precedence constraints.

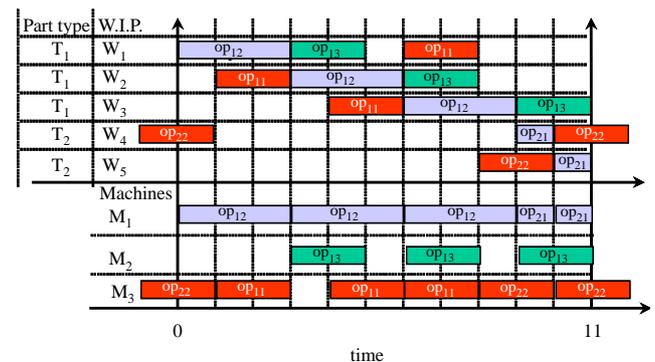


Fig. 2. Cyclic schedule.

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