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Modeling and scheduling of ratio-driven FMS using unfolding time Petri nets

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Abstract

In this paper, we focus on the analysis of a cyclic schedule for the determination of the optimal cycle time and minimization of the Work in Process (WIP for short). Especially, this paper deals with product ratio-driven FMS cyclic scheduling problem with each other products and ratios using Timed Petri nets unfolding (TPN for short). TPN slicing and unfolding are applied to analyze this FMS model. We can divide original system into subsystem using TPN slices and change iterated cycle module into acyclic module without any loss of other behavior properties.

Keywords: Petri nets; Cyclic scheduling; Work in process; Cycle time; Modeling; Flexible manufacturing systems

1. Introduction

In recent, many consumers want more kinds of products according to their desires. They also want to be distinguished from others. This new trend leads the industrial manufacturing systems to produce a large diversity of products in small quantities. The techniques of automatic transport system, new methods of production management and control are obtained by using flexible manufacturing systems (FMS for short) which are discrete-event systems.

An FMS is composed of a set of versatile machines, zig and fixture, and automatic transport system for moving parts between each job. In FMS, an important subject is to formulate the general cyclic state scheduling problem to maximize the throughput and/or minimize the Work in Process (WIP) to satisfy economical constraints. Various scheduling methods have been proposed by researchers (Hillion, Proth, & Xie, 1987; Julia, Valette, & Tazza, 1995; Korbaa, Camus, & Gentina, 1997; Lee & DiCesare, 1995; Ohl, Camus, Castelain, & Gentina, 1995; Richard, 1998; Valentin, 1994; Zuberek & Kubiah, 1993).

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Hillion (1987) proposed a heuristic based on the computation of the feasibility degree from a Petri net (PN for short) model. Also, Valentin (1994) advanced this algorithm using Timed Hybrid Petri nets and introduced available interval concepts. These methods are very interesting but they are not able to guarantee obtaining a feasible solution at the end. Korbaa (1997) showed an algorithm to find near optimal solution using a beam search approach and the regrouping algorithms. This algorithm is advanced to calculate time process. Korbaa tried to get optimal solution while minimizing the WIP. Finally, we can summarize the characteristics of these proposed methods like that transformed to event graphs from the Petri nets and search all feasibility schedules to find the best solution. Also, they get one final solution and need long time to find it.

To simplify the calculation process in scheduling problem, it may be a good method to exhibit the sequences process and analyze them. Also, if possible, we want to get all feasible solutions through short calculating time rather than previous works.

To solve these problems, we consider unfolding Petri nets to analyze the sequence process and to explain the reduced process. An ‘unfolding’ is obtained by unfolding a PN, which has the reachability information and properties of an original net. Structural analysis on ‘unfolding’ is much easier than on the original net. The advantage of unfolding is that the state space explosion can be avoided since it is based on partial order semantics. Also, to minimize the time analysis, we consider an algorithm to select an environment of shared resources which has priority over everything in the model using the transitive matrix. We analyze the system to get the best solutions based on this environment of shared resources. We divide the model into slices and create a PN slice using this concept. Then we can analyze the deadlock in system, persistence of places and transitions firing from these PN slices using a synthetic analysis method.

This paper is organized as follows. In Section 2, some definitions of Time Petri nets and unfolding are given. In Section 3, Time Petri net slice is presented. In Section 4, we introduce an illustrative model for FMS, and specially emphasize the different ways for obtaining a closed loop model. Also, we introduce the scheduling objectives and outline the problems arising during the transformation of the initial model into an unfolding TPN. Finally, in Section 5, a conclusion is given.

2. Time Petri nets and slices

In this section certain terms which are often used in the latter part of this paper are defined (Carlier & Chretienne, 1988; Liu, Itoh, Miyazawa, & Seikiguchi, 1999; Murata, 1989).

Let $N = < P, T, I, O, M_o, \tau >$ be a Time Petri net, where:

P is the set of places,
T is the set of transitions, where $P \cap T = \phi$,
$I : T \rightarrow P^{\infty}$ is the input function,
$O : T \rightarrow P^{\infty}$ is the output function.
$M_0 \in M : P \rightarrow \mathrm{IN}$ is the initial marking, IN is the set of positive integers,
$\tau : T \rightarrow \mathrm{IN}$ is a time function which associates at each transition of T a deterministic rational.

The number of occurrences of an input place P_i in a transition t_j is defined as $\#(P_i, I(t_j))$, also the number of occurrences of an output place P_i in a transition t_j is defined as $\#(P_i, O(t_j))$.