Simplification of a Petri Net Controller in Industrial Systems

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Abstract

This paper deals with the problem of prohibited states in discrete event systems modeled by Petri Net. To circumvent the forbidden states, some constraints which are called Generalized Mutual Exclusion Constraints can be assigned to them. Enforcing these constraints on the system can be performed using control places. Though when an amount of these constraints is large, a large number of control places must be associated to the system which complicates the model of controller. In this paper, the objective is to propose a general method for dropping the number of the mentioned constraints and therefore the number of control places. This method is based on combining some constraints for obtaining a constraint verifying all of them which is performed using the optimization algorithms. The obtained controller after reducing the number of the control places is maximally tolerant.

Keywords- *Supervisory Control Theory, Petri Net (PN), Generalized Mutual Exclusion constraint (GMEC), Flexible Manufacturing System (FMS).*

I. INTRODUCTION

Flexible manufacturing systems (FMS) are imperative surrounded by the set of discrete event systems (DES). A Flexible Manufacturing System (FMS) is a production system consisting of a set of matching and/or harmonizing numerically prohibited machine which are associated during an automated transportation system. Flexibility is an attribute that allows a assorted model manufacturing system to cope up with a definite level of variations in part or product style, without having any disturbance in production due to changeovers between models. Flexibility measures the capability to adapt to a wide range of possible environment. To be flexible a manufacturing system must acquire the following capabilities,

- Classification of the dissimilar production units to perform the correct operation

- Rapid changeover of operating commands to the computer controlled production machines

- Rapid changeover of substantial setups of fixtures, tools and other working units

These capabilities are often complicated to engineer through physically operated manufacturing systems. So, an automated system assisted with sensor system is necessary to complete the desires and requirements of contemporary business environment. Flexible manufacturing system has come up as a viable mean to achieve these prerequisites. The term flexible manufacturing system (FMS) refers to a highly automated GT machine cell, consisting a collection of computer numerical control machine tools and sustaining workstations, interrelated by an automated material handling and storage system and all prohibited by a distributed computer system. The reason, the FMS is called flexible, is that it is proficient of dispensation a variety of dissimilar part styles concurrently with the quick tooling and instruction changeovers. Also quantities of productions can be familiar easily to changing demand patterns.

An FMS consists of such possessions like machines, robots and buffers. Basic parts are concurrently manufactured by the system allocation the limited number of resources. Distribution resources may lead to deadlock which is a highly disagreeable situation in FMS. In deadlock states each set of two or more jobs keeps in the making indefinitely for the other jobs in the set to release resources. Consequently, the system must be avoided from toward the inside them. To estimate FMSs and also DESs, Petri Net (PN) can be used as a suitable tool for modeling. This tool is composed of places, transitions, arcs and tokens. Each transition is equivalent to an event and the tokens in the places represent the state of system. Specifically there are a lot of methods for preventing the system from entering the deadlock states based on PN models. These methods attach some organize places to the system for the reversibility guarantee. But, the number of these places may be bulky and some of them may be superfluous. Uzam et al. have proposed a method for removing the redundant control places. But in this method for a system with *n* control places, the reach ability graph must be calculated *n* times. This method is developed in where *n* Integer linear programming problems must be solved to remove the redundant control places. The advantage of these two methods is their simplification for non safe PN, though the computation takes long time and they don't give the least number of control places.

Continuation of uncontrollable transitions in the system may cause some other problems beside the deadlock states since these transitions cannot be disabled by the controller and the condition may be violated. So, the forbidden states can be separated into two sets, the states which are associated to deadlock and the states that violate the specification. Administrative control theory proposes a strategy for coping with forbidden states in DES. This theory tries to obtain the beloved function of the system by restricting its behavior. This restriction can be performed by disabling the transitions in some individual conditions. But, disabling the unmanageable transitions is impossible. In this case before firing these transitions, some convenient transitions should be disabled which leads to reducing the state space of authorized states.

Generalized Mutual Exclusion Constraints (GMECs) are the ones that verifying them may lead to complying with the measurement and avoiding the prohibited states. These constraints can be enforced on the system using control places. Giua et al. have proposed a method for conveying a GMEC to each forbidden state in safe PNs. This method has been developed in our previous work; where the GMECs can be assigned to prohibited states in non safe PNs. Enforcing the GMECs related to forbidden states on the system prevent it from incoming these states. But in these methods when the amount of forbidden states and accordingly the number of GMECs is large, a large number of control places are coupled to the system. So, some methods have been proposed for reducing the number of GMECs. In, the authors proposed a method in safe and conservative PNs for reducing the number of GMECs using invariant property. The conventional limitation is removed in the methods in and which use the over-state concept for the comparable reduction. Though, these methods are only applicable on safe PNs and do not give the least number of control places. We proposed a method in non safe PN for obtaining a control place to evade all the prohibited states. So that control place is obtained by solving an ILP problem. However this method is an extraordinary case and can cause an answer in the systems with small number of forbidden states.

II. PETRI NETS AND APPLICATIONS

Manufacturing control systems are fetching more and more complex and greatly automated, making it a hard task to achieve an efficient and real time control system. The main restriction of such systems is the lack of structure in controlled automata and the large number of states of the associated state transition structures. The large number of states resides on the comprehensive searches of overall system behavior and result finally in state-space explosion problems. One way of dealing with these problems is to model the control system with Petri nets (PN's). PN's modeling is more compact than the automata approach and is enhanced suited for modeling systems with parallel and synchronized activities. In addition, PN's has a friendly graphical representation with a powerful algebraic formulation and, thus, it has generate intense interest from scientists and researchers.

A PN is acknowledged as a particular kind of bipartite directed graph inhabited by three types of objects. They are places, transitions, and directed arcs concerning places and transitions. Formally, a PN can be defined as

$$G = (P,T, I, O) \qquad (1)$$

Where, $P = \{p1, p2,..., pm\}$ is a finite set of places, where $m > 0$;

$T = \{t1,t 2,...,tn\}$ is a finite set of transitions with $P \cup T \neq \emptyset$ and $P \cap T = \emptyset$, where $n > 0$;

$I: P\times T \rightarrow N$ is an input function that defines a set of directed arcs from P to T, where $N = \{0, 1, 2, \ldots\}$;

$O: T \times P \rightarrow N$ is an output function that defines a set of directed arcs from T to P.

A marked PN is denoted as (G, M0), where $M0: P \rightarrow N$ is the initial marking. A transition t is enabled if each input place p of t contains at least the number of tokens equal to the weight of the directed arc connecting p to t. When an enabled transition fires, it removes the tokens from its input places and deposits them on its output places. PN models are apposite to represent the systems that exhibit concurrency, conflict, and synchronization. Some important PN properties in manufacturing systems include boundedness, liveness, conservativeness and reversibility of liveness is closely associated to the absolute absence of deadlocks. A PN is said to be live if, no matter what marking has been reached from the initial marking, it is probable to eventually fire any transition of the net by succeeding through some further firing sequences. This means that a live PN guarantees deadlock-free operation, no matter what firing sequence is chosen. Validation methods of these properties include reachability analysis, invariant analysis, reduction method, siphons/traps-based approach, and simulation.

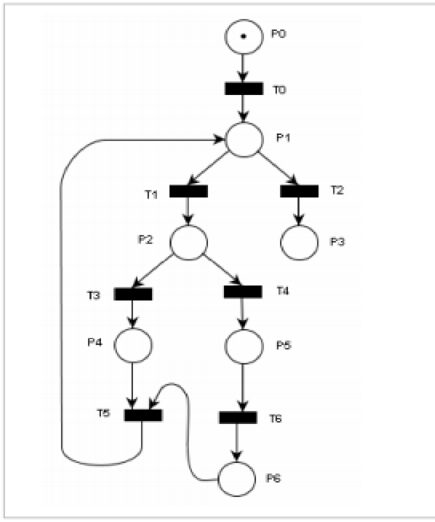

Fig. 1. The Petri Net model

A. Elementary PN Models

At the modeling stage, one requirement to focus on the main operations and their chronological or precedent, concurrent, or contradictory relationships. The basic relations among these processes or operations can be classified as follows.

1) Sequential

As shown in Figure 2 (a), if the one operation follows the other then places and transitions instead of them should form a cascade or in order relation in PNs.

2) Concurrent

If two or more operations are initiated by an event, they form a parallel constitution starting with a transition that is two or more places are the outputs of a same transition. An example is shown in Figure 2 (b). The pipeline synchronized operations can be represented with a successively connected series of places or transitions in which multiple places can be marked concurrently or multiple transitions are enabled at certain markings.

3) Cyclic

As shown in Figure 2 (c), if a progression of operations follow one after another and the achievement of the last one initiates the first one, then a cyclic structure is formed among these operations.

4) Conflicting

As shown in Figure 2 (d), if either of two or more operations can follow an operation and then two or more transitions form the outputs from the same place.

5) Mutually Exclusive

As shown in Figure 2 (e), two processes are commonly exclusive if they cannot be performed at the same time due to constraints on the usage of common resources. A configuration to appreciate this is through a common place marked with one token plus multiple output and input arcs to activate these processes.

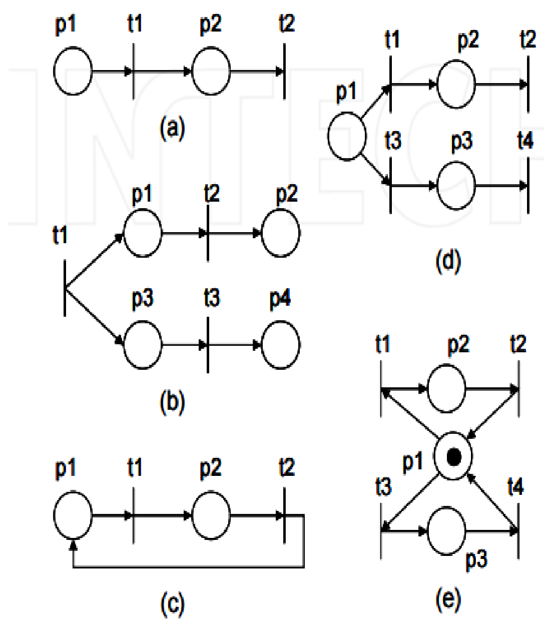

Fig 2. Basic PN Models

III. CONCLUSION

In this paper a universal method for solving the problem of the large number of control places has been proposed. This method tries to mingle the some constraints to gain a constraint verifying all of them. So, using the optimization algorithms, the constraints which can produce an answer with each other compose a group. All groups a control place can be generated. The main objective is to comprise the small number of groups for obtaining the small number of control places. Concerning the obtained control places to the system leads to a maximally tolerant controller.

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