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Deadlock Recovery for Flexible Manufacturing Systems Modeled with Petri Nets

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Abstract

This paper deals with deadlock problems in Petri nets by adding a set of recovery transitions. Different from traditional deadlock control methods by deploying control places for a net model to be controlled, this work adds transitions to a net model to recover all deadlock markings. First, we present an iterative approach. At each iteration step, an integer linear programming problem (ILPP) is formulated to design a recovery transition and the objective function is used to maximize the number of deadlock markings recovered by the obtained transition. The process is carried out until all deadlock markings are recovered. As a result, a small number of recovery transitions can be found to recover all the deadlock markings, i.e., the resulting net model with recovery transitions is live. Second, we develop another ILPP to find all recovery transitions at a time. The constraints of the ILPP ensure that every deadlock marking is recovered by at least one selected recovery transition and the objective function is used to minimize the number of selected recovery transitions. Then, a minimal number of recovery transitions are obtained by solving only one ILPP. Both approaches can make a net model live with all reachable markings. Finally, several examples are provided to demonstrate the proposed approach.

Keywords: flexible manufacturing system, Petri net, deadlock, liveness.

1 Introduction

Flexible manufacturing systems (FMSs) are a typical automated processing system to produce various kinds of raw parts by using a limited number of resources. The competition for resources by different production processes may lead to deadlocks. Deadlocks are a highly undesired situation in FMSs since they always block a system. Hence, deadlock problems must be considered and resolved when designing and operating an FMS.

Generally, there are three deadlock resolution approaches: deadlock prevention [4, 8, 12, 15, 22, 25, 44, 53], deadlock avoidance [14, 18, 45, 46, 47, 52], and deadlock detection and recovery [10, 21, 51, 20]. Deadlock prevention is an off-line computation mechanism to impose constraints on a system in order to prevent deadlock states from being reached. Based on deadlock prevention, once a control policy is established and applied, deadlocks cannot occur anymore. The approach is suitable for safety sensitive systems. Deadlock avoidance always uses an on-line mechanism to handle deadlocks. At each state, it makes
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