Design and Implementation of Deadlock Control in Manufacturing Systems

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Abstract

Effectively designing and operating an automated manufacturing system (AMS) can be of assistance to manufacturers to adapt the variety in the market in order to maintain and confirm competitiveness. Different types of parts enter in AMS at discrete points of time and are produced concurrently. These parts have to share some common resources, such as robots, machine tools, buffers, automated guided vehicles, and fixtures. The deadlocks can occur in an AMS during its operation by shared resources competition, which causes low use of some expensive and critical resources, long downtime, and can lead to calamitous results in automated manufacturing systems. Therefore, it is required to develop a successful AMS control policy to prevent deadlocks occurrencein AMS.

Recently, Petri nets have been known as one of the most robust mathematical tools for modeling, analyzing, and controlling deadlocks in resource allocation systems including AMS. To forbid deadlock occurrences in AMS, there are several methods that have been derived from the Petri net. These methods are classified into three strategies: deadlock detection & recovery, deadlock avoidance, and deadlock prevention. This thesis focuses on deadlock prevention. Three criteria are introduced in designing and evaluating a supervisor for a manufacturing system to be controlled. These criteria include behavioral permissiveness that increases the resources utilization of system, structural complexity that leads to design supervisor with a few number of monitors to decrease the software as well as hardware costs, and computational complexity that means a deadlock control policy can be implemented to huge systems. When the controlled system (deadlock-free) is obtained by using deadlock prevention methods, it is required to convert the controlled system for implementation on a programmable logic controller (PLC). PLC have been emerged as the mainstay in the execution of automation tasks. Ladder diagrams are the most popular language that is used to program a PLC.

This thesis presents a methodology based on Petri net, deadlock prevention methods that converting methods into PLC codes (ladder diagrams). In this methodology, a Petri net model of an uncontrolled system is built then the controlled Petri net model (CPN) using a deadlock prevention methods is obtained. The obtained controlled Petri net model is converted into an automation controlled Petri net model (ACPN). The automation controlled Petri net model was converted into a controlled token passing logic model (CTPL). Next, the CTPL was converted directly into ladder diagrams (LDs) using SIEMENS Step 7- 1200 PLC. Finally, the ladder diagrams were verified by using Human Machine Interface (HMI) to show the applicability, drawbacks, and strengths of these deadlock control methods. The proposed methodology was demonstrated using a case study on AMS at King Saud University, industrial engineering department, CIM lab. The proposed methodology can be applied to a wide range of discrete event manufacturing systems, which provides an effective way for PLC implementation from a controlled system model represented by Petri nets.