Chapter 6

Modeling and Control of Production Task Flows using High-Level Activity-Based Petri Nets

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ABSTRACT

This chapter presents a systematic methodology for modeling and controlling productive tasks at the organization and coordination levels in advanced production systems, especially focusing on design and implementation aspects of lean production systems. Petri nets have been successfully introduced as an effective tool for describing control specifications and realizing the control. Nowadays, large-scale and complex production systems have a hierarchical structure, and the controllers are distributed according to their physical structure. Therefore, it is natural to realize the hierarchical and distributed management and control. In this chapter, to overcome some difficulties in the modeling of production systems with a large number of elements in Petri nets, High-Level Activity-Based Petri Nets (HAPN) are defined based on condition-event Petri nets. The high-level extended net representation of the production task flows can provide more synthetic specifications for consistent management and control of production systems by a top-down refinement methodology.

INTRODUCTION

In the last two decades, manufacturing industry has experienced some notable changes from flexible manufacturing through lean production towards agile production. Lean production is a strategy that seeks to produce a high level of throughput with a minimum of inventory, lowering waste and enhancing productivity on the factory floor by the use of distributed stockpiles known as kanban (Suda, 1989). In addition to eliminating waste it seeks to provide optimum quality by building in a method whereby each part is examined, and if there is a defect the problem can be detected at the earliest possible time. The aim of Just-In-Time control is that in-process inventories have to be as

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small as possible, which means that at the exact time when a request is received by a machine, the required material and part has to be available in its input buffer, ready to be pushed. This kind of optimization can only result from a real-time synchronization between the operations in the production system. Further, agile production aims to meeting the needs of customers while controlling all the costs which are not directly related to the production of a product.

As computer technology has been continuing to be upgraded to higher level, automated production systems have been becoming larger and more complex. The manufacturing industry is forced to reorganize in geographically dispersed systems with manufacturing activities realized by distributed autonomous components. To increase the adaptation capacity and reduce the production costs for lean production, which is a complex problem involving the production management and control, many industries implement a distributed control and distributed computation to solve these complex problems, facilitating the reconfiguration of the production system. The continuous researches had motivated the collaboration between control scientists and production managers to develop optimized architectures to control and supervise the production system by organizing the cooperation between devices that are geographically distributed. Consequently, the system architecture has changed from centralized processing to distributed processing in order to meet the requirements of lean and agile software development.

Advances in mechatronics, communication, and information technologies support the feasibility of novel distributed control architectures (Cho, et al. 1999), (Duffie, et al. 1996), (Zamei, et al. 1997). Advanced large and complex production systems have a holonic or self-organizing and self-adaptive hierarchical structure like biological systems, and the controllers are locally distributed according to their physical structure. So it is natural to realize the hierarchical and distributed control of overall hardware structures. The key solution for such advanced distributed systems is to realize the cooperation, which is different from generic management and control systems. Currently, the distributed system modeling and analysis meet with difficulties related to the cooperation problem (Kotb, 2007), (Celaya, et al. 2009). Thus, it is important to specify modular structures which address the complexity of the distribution of productive operations and their integration in a highly heterogeneous environment due to the diversity of resources involved in a productive process (Wang, 1993). In industrial systems, the service oriented architecture has been successfully applied such as SCM, order entry system, etc. Other work has considered the synthesis of production models using standard manufacturing modules and product process plans using empirical methods (Villarroel, et al. 1989). However, in the low layer management and control systems, considering failures can occur due to an inadequate specification of services with particular real-time requirements in a productive system, formal approach is recommended to treat the distribution of system components in a heterogeneous environment and to integrate the system architecture for a collection of loosely coupled components. (Komoda, 2006), (Zhang, et al. 2004).

This chapter discusses the specification problem for real-time monitoring and control of different production processes involved with distributed production systems. The specification task is based on the characterization of discrete production system as a discrete event system, and then techniques derived from the Petri net are considered for system modeling and analysis. A systematical approach is presented for the specification of the production systems based on the high-level, compact, modular representation of task flows in production systems as an extension to the original Petri net formalism.