

Petri net models applied to analyze automatic sequential pressing systems

Wern-Kueir Jehng*

*Department of Industrial Engineering and Management, National Kaohsiung University of Applied Sciences, 415,
Chien-Kung Road, Kaohsiung, Taiwan, ROC*

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Abstract

In order to reduce the set-up cost, an automatic sequential press system for analyzing the performance and execution time of jobs based on Petri nets is studied. The operation processing control program is designed using Petri nets. According to the given logic specifications, sequential controlling synchronizes and coordinates the operations of various control units in the press manufacturing system. All operation steps for possibly causal fault are considered using the reachability tree of the Petri net and the expected reduction of the set-up time to fulfil zero inventory policy are also deduced in this paper. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Petri net theory has developed considerably since its introduction by Petri in 1962. Petri net theory allows a system to be modeled by a Petri net, a mathematical representation of the system. Analysis of the Petri net can then, hopefully, reveal important information about the structure and dynamic behavior of the modeled system [1]. This information can then be used to evaluate the model system and to suggest improvements or changes. Thus, the development of a theory of Petri nets is based on the application of Petri nets in the modeling and design of manufacturing systems. The application of Petri nets is through modeling fabrications. In many fields of study, a phenomenon is not studied directly but indirectly through a model of that phenomenon. A model is a representation, often in mathematical terms, of what are felt to be important features of the object or system under study. By the manipulation of the representation, it is expected that new knowledge about the modeled phenomenon can be obtained without the danger, cost, or inconvenience of manipulating the real phenomenon itself. For example, flexible manufacturing systems (FMSs) use modeling extensively. They confine both the sophisticated manufacturing equipment and the advanced computer and information technology to impart flexibility to the manufacturing operations, thereby

effectively meeting the changing needs of customers. FMS consists of several types of CNC (computer numerical control) machines, computers, robots, and automated guided vehicles and are designed to produce a great variety of products. However, these facilities pose complex problems for their planning, designing, scheduling, controlling and monitoring. This is primarily due to the inherent nature of FMS that are asynchronous concurrent systems. Modeling tools often help to address the above stated problems in FMS. There is a great demand for integrated tools that address the multi-faceted problems in FMS. Thus, Petri nets offer such an integrated solution to address effectively many issues in the design and operation of FMS [2]. Other examples include astronomy (where models of the birth, death, and interaction of stars allow the study of theories which would otherwise take a long time and require massive amounts of matter and energy), nuclear physics (where the radioactive atomic and sub-atomic particles under study exist only for very short periods of time), sociology (where the direct manipulation of groups of people for study might cause ethical problems), biology (where models of logical systems require less space, time, and food to develop), and so on.

In the early development of Petri nets, Petri [3] formulated the basis for a theory of communication between asynchronous components of a computer system. He was particularly concerned with the description of the causal relationships between events. His dissertation was mainly a theoretical development of the basic concepts from which Petri nets have been developed. The work of Petri came to the attention

* Tel.: +886-7-3814526, ext: 7101; fax: +886-7-3923375.
E-mail address: jehng@cc.nkit.edu.tw (W.-K. Jehng).

of Holt [4] and others of the Information System Theory Project of Applied Data Research (ADR). Much of the early theory, notation, and representation of Petri nets developed from the work on the Information System Theory Project and was published in the final report of that project. This work showed how Petri nets could be applied to the modeling and analysis of systems of concurrent components. Petri's work also attracted the attention of researchers at the Massachusetts Institute of Technology (MIT). The Computation Structures Group, under the direction of Dennis [5] has been the source of considerable research and publication on Petri nets. Two important conferences on Petri nets were held by the Computation Structures Group, the Project MAC (Modular, Asynchronous Control Structure) Conference on Concurrent Systems and Parallel Computation in 1970 at Woods Hole [6] and the Conference on Petri nets and Related Methods in 1975 at MIT. Both of the conferences helped to disseminate results and approaches in Petri net theory. Therefore, the IEEE Computer Society has published series of International Proceedings on Petri Nets and Performance Models. The use and study of Petri nets have increased considerably in the last few years. International workshops on Petri net theory are arranged every year as research in the application of Petri nets is becoming more widespread.

In modern enterprises, competition among the global major industrial nations has renewed interest in the issues of increasing productivity through state-of-the-art manufacturing technology [7]. Achieving a technological edge requires innovative concepts and original solutions to some very complex technical problems. FMSs, in a stand-alone mode or as part of a computer integrated manufacturing (CIM) environment. Seem to offer a very promising approach. However, the operation of these systems is a big challenge to professionals in engineering, computer science, mathematics, and management. The Petri net approach to the modeling and control of FMS and CIM systems represents a useful tool to conquer this challenge. These systems are discrete events in their operation with numerous interacting components. It is precisely the interactions of the sub-systems coupled with the discrete nature of their dynamics that are at the core of the modeling and control problem. These dynamic properties represent a time logical point view of the systems. Ramchandani [8] developed timed Petri nets (TPNs), which enable to incorporate time constraints in the PN model and determine process cycles, machine utilization and critical resources. Further development of the PN is a continuous-time stochastic Petri net (SPN). TPN represent the set of time delays presenting exponentially distributed transition firing rates. Live and bounded SPNs are isomorphic to homogeneous Markov chains [9]. Then having obtained a live and bounded SPN model with a bounded initial marking, an equivalent ergodic Markov chain can be derived and then analyzed. Furthermore, the improvement of the modeling power of SPNs make them tractable for larger systems. Generalized

SPN (GSPN) models have been devised. GSPNs are more appropriate for the modeling, analysis and performance evaluation of automated manufacturing systems [10]. Henceforth, color Petri nets (CPNs) are an important extension to ordinary PNs [11], providing elegant models with a higher level of abstraction and an important improved graphical representation capability which can reduce the size of the net: instead of having a separate net representing each component, one CPN can model all such similar components. The analysis of CPNs is mainly done with matrix-based techniques (invariant analysis) rather than with the reachability graph, since the latter is not yet fully developed. So far, Petri nets have been popularly used to model rather complex discrete event dynamic systems.

An automatic high-speed press with roll feed and scrap shear is very popular for cutting metals. In this paper, the author has designed a hydraulic drive mechanism that is used on the press for transmitting power to the slide. It is especially adapted to large pressures and slow speeds in forming, pressing, and drawing operations. Whenever possible, material should be fed to the press by a means that eliminates any chance of the operator having his hands near the dies. Feeding devices applied to the research presses as shown in Fig. 1 have the advantage of rapid, uniform machine feeding in addition to the safety features. Fig. 1 shows a double-roll feed utilizing coiled stock and scrap reels. The operation of the feed rolls is controlled by an eccentric on the cranks shaft through a linkage to a ratchet wheel which pulls the material across the die. Each time the ram moves up, the rolls turn and feed the proper amount of material for a variable eccentric, so that the amount of stock feed through the rolls can be varied. An automatic hydraulic press, equipped with a roll feed, is shown in Fig. 1. The scrap from this press, instead of being re-rolled on a scrap reel, is sheared to small lengths for easy handling. The author studied the control operations of the press machining system by the theory of Petri net and develop the methods to reduce the set-up time and cost to satisfy the theory of zero inventory (ZI). These steps are discussed in the following.

2. Petri net applied on the sequential press operations

2.1. Modeling of primitives and converted with Petri nets

Petri nets are one of most rigorous and powerful modeling tools for event-driven systems. Various extensions have greatly enhanced their applicability to different types of discrete event dynamic systems, particularly automated manufacturing systems [12]. By using a graphical, a Petri net-based software tool can form the basis of manufacturing system design. The tool provides design specification, analysis, simulation and in some cases the actual control codes for system operation. In this study, the applications of Petri nets to modeling, performance analysis and simulation of automated sequential pressing systems are examined. How a

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