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ScienceDirect

Procedia Computer Science 122 (2017) 253–260

Procedia Computer Science

www.elsevier.com/locate/procedia

Information Technology and Quantitative Management (ITQM 2017)

Decision Based Modeling of a Flexible Manufacturing Cell based on Hierarchical Timed Colored Petri Nets

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Abstract

The design techniques of flexible manufacturing systems deal, among other methods, with the application of high level Petri Nets. The modeling and simulation of a flexible manufacturing cell (FMC) can be done by implementing hierarchical techniques based on Colored Timed Petri Nets. This paper is focused on implementing decisions and strategies in a flexible manufacturing cell with colored and hierarchical techniques. In this context we discuss the decision making for machine, parts and allocated tools in transitions. The FMC model is designed based on the cell operating at the laboratory of the Faculty of Managerial and Technological Engineering, University of Oradea. In this article, we explain the design techniques using color and hierarchy to evaluate the overall performance of the cell based on part arrival decisions and part processing decisions in transitions of each sub-model of the cell.

Peer-review under responsibility of the scientific committee of the 5th International Conference on Information Technology and Quantitative Management, ITQM 2017.

Keywords: Hierarchical Petri Nets; flexible manufacturing system;decision making; colored timed Petri Nets.

1. Introduction

In the field of modeling and simulation of flexible manufacturing systems (FMS), application of various types of Petri Nets such as classical to high level Petri Nets were involved from a few decades. Research works found in the field of modeling, scheduling, resources, priority rules etc. could find a few papers focusing on decision type models with complex structure. Petri Nets are a powerful graphical and analytical tool that has been used in modeling complex manufacturing systems to evaluate their performance. In [1] and [2] the authors explain the system design, simulation and validation of Colored Petri Nets (CPN) with definition of hierarchical and non-hierarchical approaches, also describing a CPNTools software application of Colored Petri

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1877-0509
Peer-review under responsibility of the scientific committee of the 5th International Conference on Information Technology and Quantitative Management, ITQM 2017.
10.1016/j.procs.2017.11.367

Nets with support for design, editing, simulation and analysis. Development and validation of concurrent systems using colored Petri Nets is described in [3] and [4]. In [5] an explanation is given about the color specific tokens and change in colors in a system using Colored Petri Nets. In [6] a modelling of FMS is described with shared resources and also with automatic transport system using Colored-Timed Extended Petri Nets in order to analyze the system. Application of production scheduling and modeling of FMS using Hierarchical Timed colored Petri Nets (HCTPN) is described by Bozek in [7]. An FMC model constructed using CPNTools software and an analysis of the overall performance of the cell is explained in [8]. In [9] the authors explained a Fuzzy rule based manufacturing model designed using Colored Petri Nets to find solutions for conflicts and simulation and analysis for prediction of the performance. The application of fuzzy multi-criteria decision making (MCDM) method applied in robotized flexible assembly cell using dynamic scheduling to describe the best ranking solutions and decision making is described in [10]. In [11] the author described the operation of hierarchical flexible manufacturing systems with each subsystems using certain synthesis rules and single resources activity cycles. The designed model is error free and consistent with implementation of multiple types of places, arcs and tokens. In [12] the application of CPN Tools is used to model and simulate a flexible manufacturing cell and an application of certain multi-criteria fuzzy rules are employed to control the system using the MATLAB software. The paper also deals with decision making for conflict resolution.

In this paper, we briefly explain the hierarchical modeling techniques using Timed Colored Petri Nets in each sub-model in order to verify the total time of operation of the system with decisions in each transition for different tool allocations and for different types of parts (or pieces).

2. The Flexible manufacturing cell, arrival time and measured processing time for parts processing

The Flexible Manufacturing Cell is consisting of one CNC machining centers TMA 55 OP based on FANUC system, two ABB IRB 1600 robots equipped with pneumatic gripping devices, conveyor transfer system and a separate storage area for specific raw materials and finished parts, presented in Fig 1 (a). The modeled flexible manufacturing cell operates at the laboratories of the Faculty of Managerial and Technological Engineering, University of Oradea.

Fig. 1. Example of (a) Flexible manufacturing cell from Faculty of Managerial and Technological Engineering, University of Oradea, (b) Drilling processing, (c) Contour processing

In this proposed Hierarchical model, the times for arrivals of the parts in the cell associated with resources from places PA, PB, PC, PD, and PE are mentioned in Fig 2. The part arrival times are as follows: from PA for P1= 0 sec, P1=8000 sec, from PB for P2= 600 sec, P2= 8500 sec, from PC for P3= 1500 sec, P3= 10600 sec, from PD for P4=2800 sec, P4=12400 sec and from PE for P5= 5200 sec, P5= 16000 sec in the system. The parts are processed on the CNC machine and the times observed for each part are as follows: P1 = 336 sec; P2 = 458 sec; P3 = 1158 sec; P4 = 2160 sec and P5 = 2460 sec. Below in the Fig 1 we are showing the machining