International Conference on Economic Engineering and Manufacturing Systems
Braşov, 25 – 26 October 2007

PETRI-NET BASED APPROACHES TO FLEXIBLE MANUFACTURING SYSTEMS

Mihaela - Elisabeta CIORTEA*, Liviu MORAR, Adrian PISLA**, Camelia VLAD****
* University "1 DECEMBRIE 1918" Alba Iulia, Romania
** Technical University of Cluj-Napoca, Romania

Abstract: This paper describes the planning process in flexible manufacturing systems. Flexible manufacturing system consisting of machines, computers, robots and automated guided vehicle. The skeleton and the functionality of a Petri Net Toolbox, embedded in the MATLAB environment, are briefly presented, as offering a collection of instruments devoted to simulation, analysis and synthesis of discrete event systems. The integration with the MATLAB [1] philosophy responds to the general interest manifested by educators for enlarging the compatibility between the traditional background of Control Engineering applications and the novelty of discrete-event-systems scenarios.

It explains a scheme of labelling and firing which makes modelling convenient for complex systems whose constraints are difficult to express only in terms of firing duration.

The system manufacture choose is from the undertake S.C. APULUM S.A. Alba Iulia.

Timed Petri nets are used to model operational and routing flexibility in production systems. A generalized multi-productive machine module is defined, adapted to system feature, repeated and connected to compose the TPN models of production systems with different levels of routing and operation flexibility.

Keywords: Petri nets, manufacturing systems, MATLAB

1. Introduction

Petri net theory is developed twofold:

- Formal Petri net theory – elaborates the means, methods and notions for the use of Petri nets,
- The applicative theory of Petri nets – aims to use Petri nets for system modelling, system analysis and to obtain results.

Petri net based distributed system modelling takes place at the state level: it determines the actions that take place in the system, the states that precede these states and the state in which the system will pass after the actions have taken place. By simulating the state model through the Petri nets, we obtain a description of the system's behaviour.

This paper presents a concrete step-by-step methodology using t-timed ordinary modular PNs for modelling, analysis, synthesis, performance evaluation and simulation of random topology dedicated production systems, viewed as surplus based systems, composed of workstations and buffers, where machines fail and are repaired randomly.

For a random topology dedicated production system, whether single or multiple part type or cyclically scheduled, with finite or infinite capacity buffers, the following are accomplished:

1. Production system decomposition-analysis.
   - generic modules and generic PN modules that correspond to the one input buffer-one machine-one output buffer transfer chain module, two input buffers-one machine-one output buffer assembly module, one input buffer-one machine-two output buffers disassembly module and two parallel machines module,
   - generalized modules and generalized PN modules that correspond to the n_{TCi} machines-(n_{TCi} + 1) buffers transfer chain module, n_{Ai} input buffers – one machine – one output buffer assembly module, one input buffer – one machine – n_{Di} output buffers disassembly module and one input buffer – n_{Pi} parallel machines – one output buffer module.
2. Production system composition-synthesis.
   - component connectivity, this is determined by places fusion at the respective module connecting points,

- component complexity and overall system complexity, this is determined by calculating for any random topology dedicated production system, the total number of the PN module nodes and the overall PN system nodes.

3. Production system constraints.
4. Production system simulation and performance evaluation.

2. Production system modules

A production system is usually viewed as a network of machines/workstations and buffers. Items receive an operation at each machine and wait for the next operation in a buffer with finite capacity. Random machine breakdowns disturb the production process and blocking may occur.

Production control policies may by classified as token-based, time-based and surplus-based [2, 3]. When considering simple manufacturing systems, analytical results produced thus far have demonstrated the superiority of surplus-based system.

The production systems concerned here are dedicated machine production systems. The use of modular subsystem in production systems modelling is a need, as this allows the independent modification of the model, resulting in increased flexibility that meets one of the major requirements of such systems and allows the use of more efficient advanced performance evaluation and analysis techniques, as distributed simulation [4].

An Ordinary Petri Net is a bipartite directed graph defined as the five - node:
$PN = \{P, T, I, O, m_0\}$, where $P = \{p_1, p_2 \dots p_n\}$ is a finite set of places, $T = \{t_1, t_2, \dots t_n\}$ is a finite set of transitions, $P \cup T = V$, where V is the set of vertices and $P \cap T = \Phi$, $I : (P \times T) \rightarrow N$ is an input function and $O : (P \times T) \rightarrow N$ an output function with N a set of non-negative integers, and m_o the PN initial marking. Places represent conditions, transitions represent events and arcs direct connection, access rights or logical connection between places and transitions.

The physical signification of the sprockets and the transitions is (figure 1) [5]:
sprockets:
M1 – sorting; M2 – isostatic pression; PM1 – the remaking of the lot to assortment M1; TT1 – discharge the bunker; DW – the operation of stockage in bunker; PM2 – the remaking of the lot to isostatic press M2; TT2 – transport with electropiler; TT3 – Discharge from M2 in truck; BOXA, AUT1 – general which resource models the transport devices (palet + cup).
transitions:
t1– the fixation for the process of assortment M1; t2 – the completion remaking on M1 and beginning of warehouse transport; t3 – the completion of the transport of the lot of to device and begin his stockage in warehouse; t4 –the placement of the lot in warehouse (cup of electropiler) and his preparation were transported to M2; t5 – the fixation for the process of isostatic press M2; t6 – the completion remaking on M2; t7 – the completion placement in truck of the lot remarked to isostatic press.

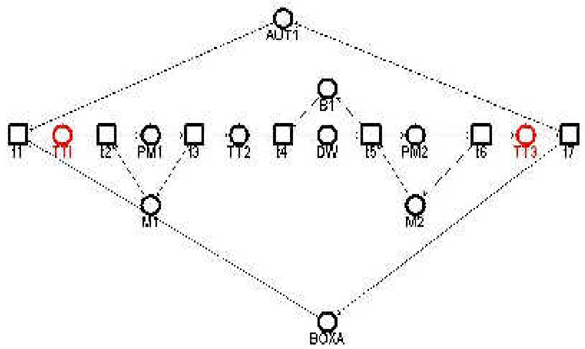


Figure 1. Generalized production system modules

The incidence matrix (figure 2) [6] **A** for a PN consisting of n_p places and n_t transitions is defined as **A** = $[a_{ij}]$, where $a_{ij} = a_{ij}^{+} - a_{ij}^{-}$, $a_{ij}^{+} = w(i, j)$ is the arc weight from transition i to its output place j and $a_{ij}^{-} = w(j, i)$ is the arc weight to transition i from its input place j. a_{ij}^{+}, a_{ij}^{-} and a_{ij} represent the tokens added, removed and totally changed in a place j by the firing of transition i, respectively. The incidence matrix cannot represent self-loop.

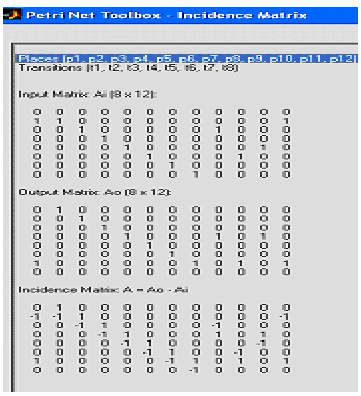


Figure 2. Incidence matrix

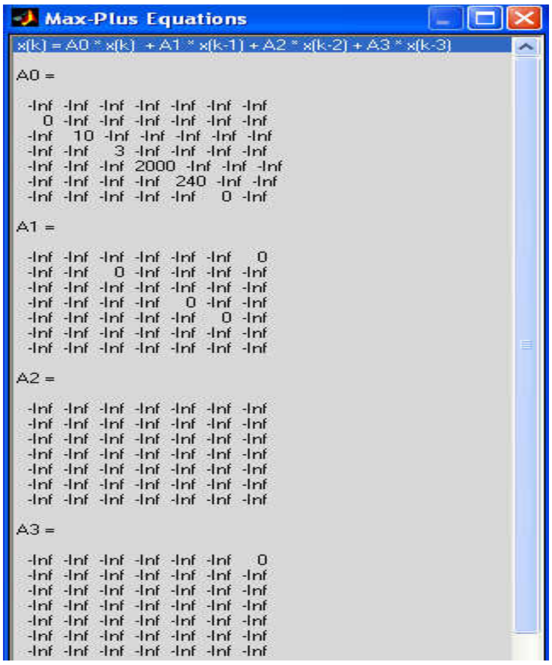
For place-timed event graphs [7], the PN Toolbox is able to directly derive the max-plus state-space representation from the topology and initial marking of a marked graph, in an implicit form:

$$x(k) = \bigoplus_{i=0}^{M} [A_i \otimes x(k-i) \oplus B_i \otimes u(k-i)]$$

$$y(k) = \bigoplus_{i=0}^{M} [C_i \otimes x(k-i) \oplus D_i \otimes u(k-i)]$$

$$k = \overline{1, N}$$

where M denotes the maximal number of tokens in the initial marking and N stands for the number of simulated iterations. The components of the input vector $u(k) = [u_1(k), u_2(k), \ldots, u_m(k)]^T$ and those of the output vector $y(k) = [y_1(k), y_2(k), \ldots, y_m(k)]^T$ represent the k-th firing moments of the m source transitions and of the p sink transitions, respectively. In a similar manner, the state vector $x(k) = [x_1(k), x_2(k), \ldots, x_m(k)]^T$ corresponds to the n transitions in the net that have input and output places.



```
Max-Plus Equations
x(k) = A0 * x(k) + A1 * x(k-1) + A2 * x(k-2) + A3 * x(k-3)
A0 =

 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
    0 -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf   10 -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf    3 -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf 2000 -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf  240 -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf    0 -Inf

A1 =

 -Inf -Inf -Inf -Inf -Inf -Inf    0
 -Inf -Inf    0 -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf    0 -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf    0 -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf

A2 =

 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf

A3 =

 -Inf -Inf -Inf -Inf -Inf -Inf    0
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
 -Inf -Inf -Inf -Inf -Inf -Inf -Inf
```

Figure 3. The state representation max-plus associated to the net

Avoiding the deadlock refers to using the control structure of Kanban type, which monitors the number of elements accepted in the system for all activities between the transitions that model the beginning of the operations served by an automated system (automated system = robot). The simulation experiments used to build the representative points on these surfaces take place during the time units necessary for transport. For the average time period needed to manufacture a product, we obtain the graphical representation analyzed in the following figures:

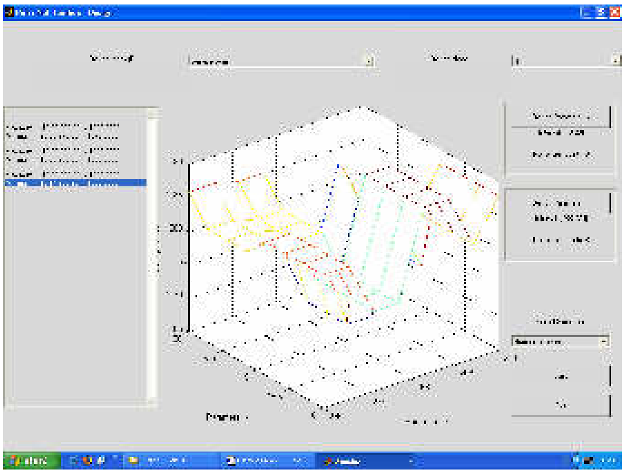


Figure 4. The window opened by the PN Toolbox for Design options

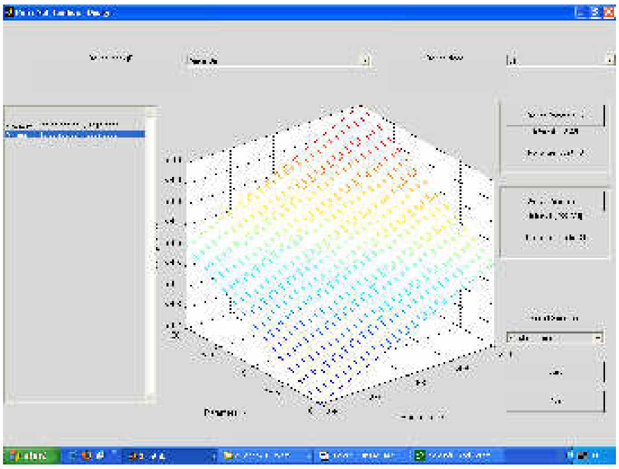


Figure 5. Graphic representation of the average period for product manufacturing

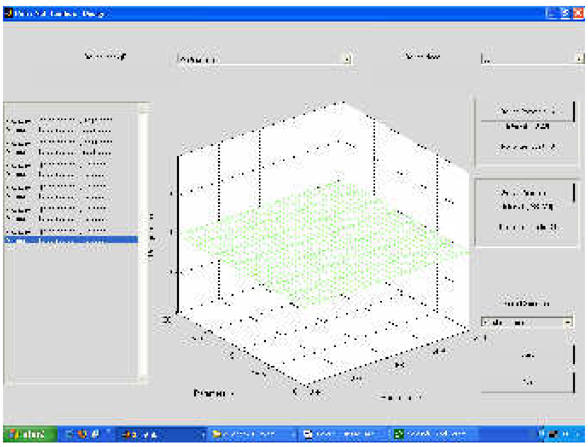


Figure 6. Graphic representation of the average period of M machine operation time

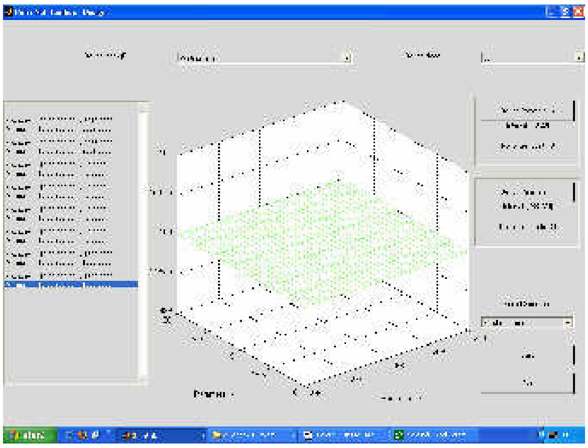


Figure 7. Graphic representation of the average number of items from the warehouse

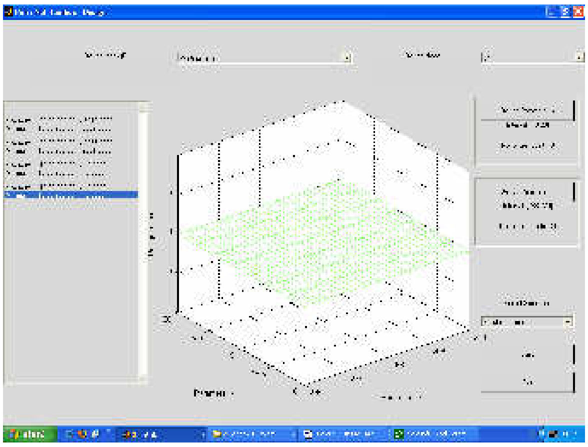


Figure 8. Evolution of the average operation period for the M1 machine depending on the μ

Within the experiment executed in relation to a parameter, Petri Net Toolbox memorizes all the indicators that refer to the positions and transitions of the analyzed model. The information referring to the average operation time of machines can be obtained directly by selecting properly the respective indicators.

5. Conclusions

The problem of transportation from the source to the destination, going through intermediate centres, analyzed by linear and graph programming models of the type of transportation network can also be modelled through Petri networks. The algorithms for determining characteristics are basic components of the algorithms developed to determine the optimum values required by the objective of the transport activity.

References

1. www.mathwork.com. Accessed: 2007-03-15
2. Conway, R., Maxwell, W., McClain, J.O., Thomas L.J.: *The role of work-in-process inventory in serial production lines.* The guide to computing Literature, ISSN 0030-364X, Vol. 36, Issue 2, March-April 1988, p. 229-241
3. Tsourveloudis, N., Dretoulakis, E., Ioannidis, S.: *Fuzzy work-in-process inventory control of unreliable manufacturing systems.* Information Sciences, DOCIS, 2000, Vol. 127, Issue 1-2, p. 69-83
4. Nketsa, A., Vallete, R.: *Rapid and modular prototyping based Petri nets and distributed simulation for manufacturing systems.* Applied Mathematics and Computation, SSM, Vol. 2, 2001, p. 265-278
5. Morar, L., Ciortea, E.M.: *The Improvement Of The Manufacturing System Through The Out Of Order Detection Of Guys Ceramic Fashioned Raw Piece*. Proceedings of The 4th International Federation of Automatic Control Conference on Management and Control of Production and Logistic, IFAC MCPL 2007, Sibiu, 27-30 September 2007, Romania
6. www.ac.tuiasi.ro/pntool/. Accessed: 2007-03-15
7. Păstrăvanu, O., Matcovschi, M., Mahulea, C.: *Aplication of Petri nets in discreet systems analysis (Aplicații ale rețelelor Petri în studierea sistemelor cu evenimente discrete).* “Gh. Asachi” University Press, Iași, Romania, 2002 (in Romanian)