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DESIGNING A CONTROL STRUCTURE FOR DISCRETE EVENT SYSTEMS DESCRIBED BY PETRI NETS

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Abstract: *Petri net models are used to describe discrete event and hybrid systems.The paper presents the Petri network modeling a control structure for a manufacturing system and the simulation of the respective model using the Arena® software, in order to analyze and emphasize the performance characteristics of the system.*
Key words: *Discrete, control, Petri nets, Arena®, simulation*

1. INTRODUCTION

Since the introduction of Petri nets, one may observe an increasing interest referring to the related theory and application in modeling and analysis of the asynchronous systems. Designing a control structure for discrete event systems described by Petri nets is mainly imposed by the necessity of solving specific problems that usually require a different approach of the classic control methods used for dynamic systems time-driven (Zhou&DiCesare, 1993), (Haoxun, 2000).

The considered discrete event system is a manufacturing one. Successively applying the stages of the hybrid synthesis method, one has obtained the Petri network that models the control structure. In order to perform the simulation and to analyze this structure, the authors developed the corresponding Arena® model, emphasizing the number of manufactured pieces, the operational time, the degree of resources usage and the maximum number of pieces that may be stored in each deposit for an optimum calibration performance, in order to avoid pitching.

These results can be used in future researches regarding control structures of manufacturing systems of a discrete event type that may allow further performance and optimization studies.

2. HYBRID SYNTHESIS OF THE DISCRETE EVENT MANUFACTURING SYSTEM

Petri nets represent a graphical and mathematical tool that provides an excellent environment for modeling, formal analysis, and design of discrete systems. The integrated engineering systems are of event-based type and often asynchronous, comprising concurrent, sequential, and large scale activities. In this respect, in order to describe a manufacturing system as a discrete event system, one has to define the discrete state-space and the state transition mechanism, asynchronous event-driven type, as illustrated in figure 1.

The process has as inputs a certain number of customers, that are entities whose nature depends on the specificity of the process. Each operation performed by the process represents a certain type of service for the customer, so that, after performing a complete operation, one may say that the customer has been fully served and is allowed to leave the process. Thus, the output of the process is given by the number of customers fully served.

Fig.1. Event-driven manufacturing system scheme

In this respect, the analyzed manufacturing system has the following resources:

- three digital command machines M1, M2, M3;
- two manipulator robots R1, R2;
- two inter-operational deposits D1, D2, that have a capacity of 2, respectively 4 pieces,

as presented in figure 2 (Pastravanu et al., 2002). The inputs are the raw pieces RP1 and RP2, and the associated technological operational flow consists in the following operations that produce the FP1 and FP2 finite pieces: the piece fitted on a paddle is automatically loaded and then manufactured on M1, then R1 carries the piece to D1(D2) deposit, where the piece waits until is automatically loaded and manufactured on M2 (M3), and finally R2 takes the piece to the output 1(2), where PF1(PF2) is taken out of the paddle.

According to the operational flow, after running through the stages of descendant and ascendant synthesis, one obtained the final model of the system, illustrated in figure 3. The positions p_1 and p_2 model the availability of the paddles and represent the general resources. Refining these positions allows the emphasis of the specific non-shared resources RP1-FP1-M2, modeled by p_{14}, and RP2-FP2-M3, modeled by p_{24}, of the non-shared storage resources D1, modeled by p_{13}, and D2, modeled by p_{23}, and of the shared resources M1, R1, and R2.

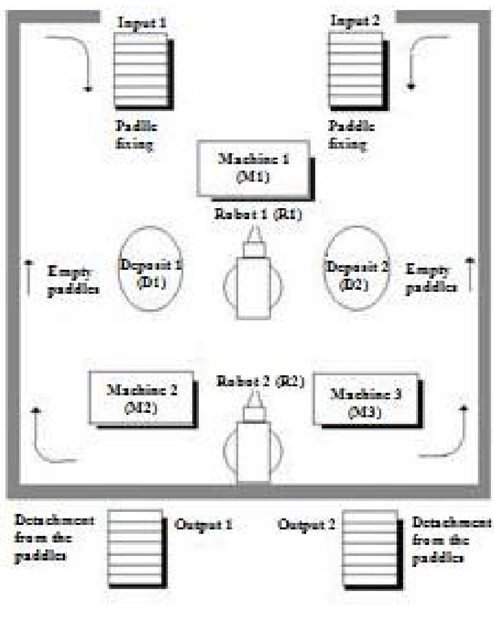

Fig.2. Manufacturing system structure

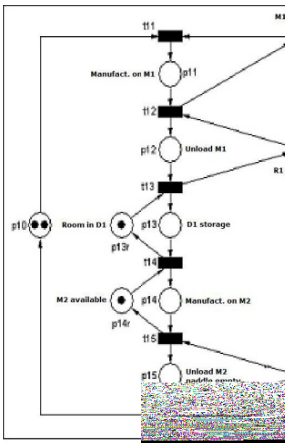

Fig. 3. Petri nets final model

3. SIMULATION OF THE CONTROL STRUCTURE

In order to verify the proper functionality of the obtained control structure, the authors performed a simulation using the *Visual Object Net ++ 2.7a* software tool, used for the design and simulation of Petri nets. According to the representation in figure 4, that presents the state of the system led in an operating point, one may observe that the obtained control structure ensures the specified succession of the operations, the proper allocation and dismissal of non-shared resources and storage resources, and the mutual exclusion at shared resources allocation. Furthermore, for proper performance studies related to the applied control structure upon the considered manufacturing system, the authors elaborated the system model using *Arena®* software programs (Kelton, Sadowski&Sturrock, 2007) for modeling, simulation, and analysis, on the basis of Petri nets.

Model elaboration with *Arena®* (Rockwell Automation,2010) generates a structure of the sub-models, presented in figure 5, corresponding to the main operations from the complete model. The sub-models consist of:

- *P11, P21, P12, P22* – process with *Seize-Delay type* action,that allocates the respective machine and performs the piece in a pre-defined time interval;
- *Unload M11, unload M12, unload M2, unload M3*-process with *Seize-Delay-Release type* action, that allocates the respective robot, unloads the machine in a pre-defined time interval and releases the robot;
- *Release M11, release M12, release M2, release M3* – process with *Release type* action, that releases the respective machine.

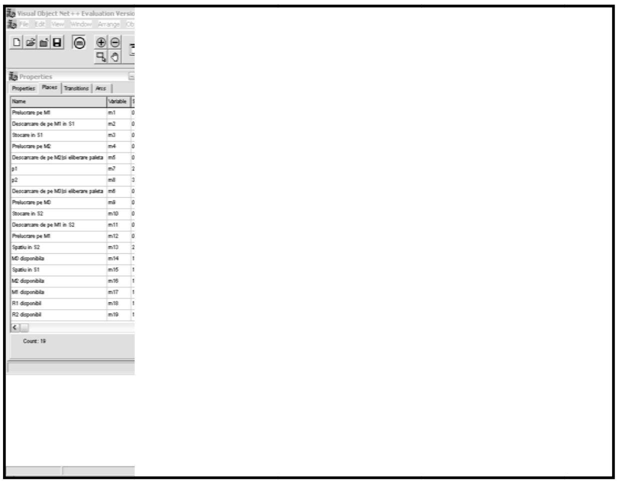
Fig. 4. Control structure simulation with *Visual Object Net ++*

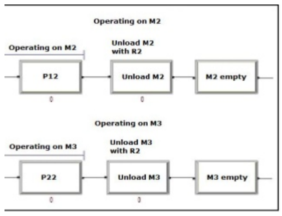

Fig. 5. *Arena®* sub-models

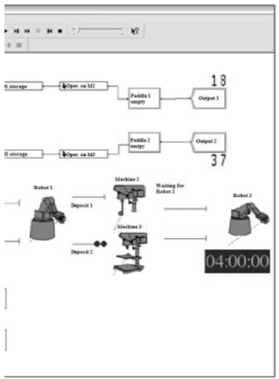

Fig. 6. System operation state simulation after 4 hours of work

Figure 6 presents the simulation of the system operation state after 4 hours of work, in order to emphasize certain specific aspects, such as: the number of used paddles and the usage degree, corresponding to each flow, the number of pieces waiting to be processed on M1, the R1 and R2 robot state, as well as the type of handled pieces and the number of stored pieces in each of the two deposits. Arena®' Process Analyzer generated possible operational scenarios; thus, considering the *paddle 1 capacity* and *paddle 2 resources* as control variables, one obtained as answers an *optimum of 2 paddles on flow 1 and 3 paddles on flow 2*, the *indicated capacity of the deposits D1 and D2 being of minimum 1, respectively 2 pieces.*

4. CONCLUSIONS

Considering the obtained results, one may conclude that the paper has answered the research question, namely presenting a discrete event control structure of a manufacturing system, elaborating the Petri net hybrid synthesis and Arena® simulation that allows performance and optimization studies.

As future directions, one would have to consider the fact that the hybrid synthesis method deals with untimed Petri nets, so that the control structure solves the problem of mutual exclusion at shared resources allocation without considering the performance aspects regarding the processing times, as well as possible failure operations and time delays generated by repairing and maintenance activities.

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