Modeling a Manufacturing System by Using XML - Petri Nets Technology

A Pop¹, F S Blaga¹, M P Ursu², C Bungău³ and V Hule³
¹University of Oradea-Romania, Department of Industrial Engineering, Universitatii Street, No. 1, Oradea, 410087, Romania
²University of Oradea, Department of Computers and Information Technology, Universitatii Street no.1, Oradea, 410087, Romania
³University of Oradea, Department of Mecatronics, Universitatii Street no.1, Oradea, 410087, Romania

E-mail: alinpop23@yahoo.com

Abstract. In this paper we propose an approach of modeling and simulation of a manufacturing process based on timed colored Petri nets, by developing an application based on XML (eXtensible Markup Language) technology. The architecture of an XML file that characterizes a Petri nets includes specific attributes for positions, transitions, arcs and variable declarations and color sets. This makes it possible to modify the model from a structural point of view very easily by adding lines of code for the required colors, positions, transitions and arcs. In order to generate the default model and to customize the XML-type structure, an application was created where characteristic parameters of the manufacturing process will be introduced as well as the values of the program entry. The manufacturing system considered is the realization of the sunroof component within a company. During the simulation process, the working time will be considered as 8 hours. When product demands change, the simulated model can be modified very quickly to perform the analysis according to the new requirements. The arrangement of the entities of the production system can be reconfigured, the production process can be adjusted and the resources reallocated according to the simulation results.

1. Introduction
CPN Tools is a modeling and simulation instrument which uses Petri nets to represent the models of the systems [1]. This is a combination between the graphic representations of the Petri nets and the programming language CPN ML (Markup Language). Because it allows the definition of colors which are associated to positions and transitions, it becomes possible to attain important information from the structure and performance dynamics of a system, by means of modeling and simulation.

This paper proposes an innovative way to make models based on colored Petri nets. Within such a colored Petri net model, in order to be able to convert input quantities we need conversion rules INPUTS-to-Models based on XML technology. The result will consist of a correct XML document from the point of view of the CPN Tools – Document Type Definition (DTD) structure. Paper [2] describes the syntax and semantics of language PNLM (Petri Nets Markup Language).

Using CPN Tools, a Petri net model is a set of elements which consist of positions, transitions, arches, marks, variable declarations and operational timings [3]. Objectively, a specific file of an XML-type CPN Tools model [4] must contain information about the characteristics of all model...
elements. The structure of an XML file of type CPN Tools DTD can be described in the following way [1] (figure 1):

![XML - CPN Tools Document type definition.](image)

In order to properly define a position by means of XML technology, the following attributes are defined: position ID, coordinates in the workplace, position type, colors set, initial mark. A transition is described by means of attributes: position, condition, timing, code and priority.

2. Description of the application

This paper presents a web application that generates XML files specific to CPN Tools software, which are required for the modeling and simulation of a production system within an automotive components factory. The organizing and planning of the production process are essential in order to attain the shortest times and minimal costs of the products manufacturing. Also, during the production process frequent changes may appear referring to the necessary operational timings and resource management.

The application can be used for the modeling of a manufacturing process with a limited number of 10 operations. If a new fabrication process requires more phases, the application can be adjusted in a relatively short time.

The XML CPN TOOLS Generator application consists of 5 steps for the generation of the XML-type file.

**Step 1**

Within the analyzed production process, the main operations that are included in the production flow will be distinguished. A main operation is defined as the production operation that will directly generate the finite product realization process, and the secondary operations will be defined as the complementary activities for the preparation of the elements that belong to the production process (figure 1).

The number of the main operations is input in step 1. Based on this information, the input fields for name and timing for each operation will be generated.

**Step 2**

Depending of the number of operations input during step 1, step 2 allows the input of the names and timings required by the main operations of the production process. Timings are expressed in seconds.

**Step 3**

This phase allows the identification of the main operations to which secondary operations will be associated.

**Step 4**

The name and the finalizing timing required for each secondary operation will be specified.
Step 5
During step 5 the XML file specific to CPN Tools software will be generated, and then this file will be loaded into CPN Tools software (figure 3).

3. Modeling and Simulation of the Automotive Sun Visor
In the classic approach of modeling and simulation of a production system by means of colored Petri nets, we will use a program that provides the user with a graphical interface. The person in charge of the organizing and optimization of the production process must have specific knowledge in the Petri nets in order to generate the model. In the case that is studied in this paper, the Petri nets model is generated with CPN Tools program by means of the above-mentioned application, following the 5 steps that were described in chapter 2.

3.1. Description of the Fabrication Process
The analyzed case is the fabrication process of an automotive sun visor (figure 4), which requires the completion of 10 operations of preparation and component assembly. The sun visor is made of 7 components: 1 – leaf spring, 2 – textile material, 3 – aluminum tube, 4 – aluminum tube lid, 5 – metallic spring, 6 – metallic spring lid, 7 – case (figure 5).
Figure 4. Automotive sun visor.

Figure 5. Automotive sun visor – exploded components view.

Only one component is used during the first two operations, the leaf spring, which will be cleaned by removing any impurities (grease), and will be fitted with receive a longitudinal polypropylene strip.

During operation 3, components 1 and 2 are added, and then the textile material is glued on. After completing the gluing cycle, the workpiece is removed from the machine and is transported to the next operation, and in the same time the component 3 is prepared to be used during operation 5. Table 1 shows the order of the operations, and one can see that component 5 is fitted during operation 7. It is to be mentioned that only one operator is needed for operations 4 and 7 [5].

Table 1. Steps of the automotive sun visor production.

| Nr. | Operations names              | Operations order | Components     |
|-----|-------------------------------|------------------|----------------|
| 1   | Steel strips cleaning         | 1                | Component 1    |
| 2   | Polypropylene strip fitting   | 2                | Component 2    |
| 3   | Textile material gluing       | 3                | Components 1, 2|
| 4   | Preparation of aluminum tube  | 4                | Components 3, 4|
| 5   | Excess trimming, assembling   | 5                | Components 1, 2, 3, 4 |
| 6   | Punching                      | 6                | Components 1, 2, 3, 4 |
| 7   | Preparation of leaf spring    | 7                | Components 5   |
| 8   | Final assembling              | 8                | Components 1, 2, 3, 4, 5, 6 |
| 9   | Testing                       | 9                | Components 1, 2, 3, 4, 5, 6, 7 |
| 10  | Checking                      | 10               | Components 1, 2, 3, 4, 5, 6, 7 |

Table 2 shows the operations completed during the fabrication process, with their correspondent operational timings.
Table 2. Steps of the automotive sun visor production.

| Name                          | Timing [s] |
|-------------------------------|------------|
| Steel strips cleaning         | 43         |
| Polypropylene strip fitting   | 87         |
| Textile material gluing       | 80         |
| Preparation of aluminum tube  | 32         |
| Excess trimming, assembling   | 44         |
| Punching                      | 9          |
| Preparation of leaf spring    | 26         |
| Final assembling              | 50         |
| Testing                       | 54         |
| Checking                      | 44         |

3.2. Generation of Petri nets model as an XML file

In order that the resulted XML file to be correct from the operations sequence point of view, the main assembling operations and the secondary operations are identified. During step 1 the number of 8 main operations is input (figure 6), and during step 2 the names and timings of each operation are input (figure 7).

Figure 6. Step 1 – XML CPN TOOLS generator application.

Figure 7. Step 2 – XML CPN TOOLS generator application.

The secondary operations for the preparation of components 3 and 5 respectively, and their operational timings will be added during steps 3 and 4 of the application (figure 8, figure 9).
After the introduction of the input parameters, during step 5 the XML-formatted file will be downloaded.

The web application sends to the XML code generation algorithm the following input quantities: the main operations string with their attributes (names and operational timings), and the secondary operations string with their attributes (name, timing, position). Each element of the main operations string will be converted into a transition (figure 10).

The XML code for positions will be generated in a similar way. It is to be noted that the number of the generated positions will be one unit greater than the number of transitions, and the number of arches is two times greater than the number of transitions (figure 11).

Figure 12 shows the scheme for generating the XML code corresponding to the model with the petri nets. Each main operation corresponds to a position and a transition with a specific id in the string.

The result of the XML file loading into CPN TOOLS is a model with 13 positions and 10 transitions. Each transition represents a phase of the fabrication process with its associated timing. Because the modeling and simulation of the fabrication process tracks the completed products at the end of this process, the 13 positions that were generated by the Petri net model are defined with the same color.

The time taken into account in modeling the manufacturing process is an 8-hour shift. Figure 13 shows the positions P12, P13 and the transition T10 corresponding to the secondary operation, as well as the positions P14, P15 and the transition T11 corresponding to the secondary operation. Position P1 is receives token immediately when the transfer of component 1 to operation 2 is complete.
Figure 12. The Petri net model generation algorithm, using XML technology.

Figure 13. The CPN Tools model of the automotive sun visor production system.
4. Conclusions
The field of modeling and simulation of production systems is diverse and can take different forms. The methods of conversion and interconnection of the various instruments that are used in the analysis of the production systems performance parameters are very important. Thus, CPN Tools, which is the most used software for Petri nets modeling and simulation, can be used either directly to generate models by means of the user graphic interface, or by means of XML files that were generated by applications.

This paper presents the way that a CPN Tools formatted model can be generated by means of a web application. This consists of 5 steps which define the main operations and the secondary ones that make up the fabrication process. The fabrication of an automotive sun visor within a specialized company was considered as an example. The optimization of the fabrication process requires successive modifications of the input data, such as number of operations and the operational timings for each operation. The generation of the model with CPN Tools by means of this method makes the use of the modeling and simulation program easier and faster, without the need of advanced knowledge in the field of the colored Petri nets.

All the activities and states of the fabrication system are automatically converted into positions, transitions, arches, marks and timings corresponding to each operation.

5. References
[1] http://cpntools.org/2018/01/08/can-cpn-tools-open-models-from-design-cpn/- Accessed on December 2019
[2] Weber, M. and Kindler, E. 2003 The Petri Net Markup Language, In: Ehrig, H.: Petri Net Technology for Communication-Based Systems, Advances in Petri Nets 2472 (Berlin: Springer) 1-21
[3] Blaga F, Stanasel I, Pop A, Hule V and Buidos T. 2014 Consideration on flexible manufacturing cell modeling with timed colored Petri nets. Annals of the University of Oradea 1 p. 299-302
[4] Boubeta-Puig J, Díaz G, Macià H, Valero V and Ortiz G 2017 MEdit4CEP-CPN: an approach for complex event processing modeling by prioritized Colored Petri Nets Inf. Syst. https://doi.org/10.1016/j.is.2017.11.005 accessed on November 2019
[5] Pop, A. 2019 The Use of Timed Colored Petri Nets in a Manufacturing Process Modeling and Simulation Nonconventional Technologies Review, 23(1) Retrieved from http://www.revtn.ro/index.php/revtn/article/view/7 accessed on December 2019

Acknowledgments
This paper was funded through the project “SmartDoct - High quality programs for doctoral students and postdoctoral researchers of the University of Oradea to increase the relevance of research and innovation in the context of regional economy ”, ID / Project code: 123008, co-financed from the European Social Fund through the Human Capital Operational Program 2014-2020 ” and thanks to the Doctoral School of Engineering Sciences (University of Oradea) facilities at the scientific infrastructure.