ANNALS OF THE ORADEA UNIVERSITY
Fascicle of Management and Technological Engineering
ISSUE #1, MAY 2014, http://www.imtuoradea.ro/auo.fmte/

CONSIDERATION ON FLEXIBLE MANUFACTURING CELL MODELING WITH TIMED COLOURED PETRI NETS

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Abstract - This paper presents how color Petri nets can be used in flexible manufacturing system models.. It is studied the cell from the Faculty of Engineering Management and Technology. In this cell process four parts: two pieces of revolution and two prismatic parts. In a first variant coloured Petri nets model is made without taking into account the time factor. This does not allow a prioritization of processing and the evaluation of manufacturing cycle time. If we consider the factor of time, coloured Petri nets model allows prioritization processing by the fact that each color is associated with a part it can be attach timing. May also be taken into account the processing times through timings associated with the transitions.

Keywords - Flexible cell, coloured Petri nets, color, timing, modeling and simulation.

I. INTRODUCTION

The performances evaluation of flexible manufacturing cells is a important goal for decisional factors of manufacturing programming.

Colored Petri Nets are part of high-level Petri networks [1], [2] and offers the possibility of modeling of complex systems, resulting models are much simpler (fewer positions and transitions) structurally than models with ordinary Petri Nets (networks type Position /Transition) [3], [4]. Also, colored Petri nets offer the possibility for parametric models [5].

The introduction of the time factor in the model with colored Petri nets model contributes to increased accuracy relative to model systems [3], [6].

Colored Petri Nets are used with success in modeling and simulation of concurrent systems: computer networks, communication systems [5], [7].

II. MODELING OF THE FABRICATION LINES BY MEANS OF PETRI NETWORKS

A) Flexible cell description

The layout flexible manufacturing cell is shown in Figure 2. The cell is composed of:

1) Power station (1);
2) Evacuation station (2);
3) Lathe CNC CONCEPT TURN 55 (3);
4) Control equipment (FANUC or SIMESS) of milling machine (4);
5) Milling machine CNC CONCEPT MILL 55 (May);
6) Control equipment (or FANUC SIMESS) the lathe (6);
7) Mitsubishi RV-2AJ robot (7);
8) Handle the moving robot (8).

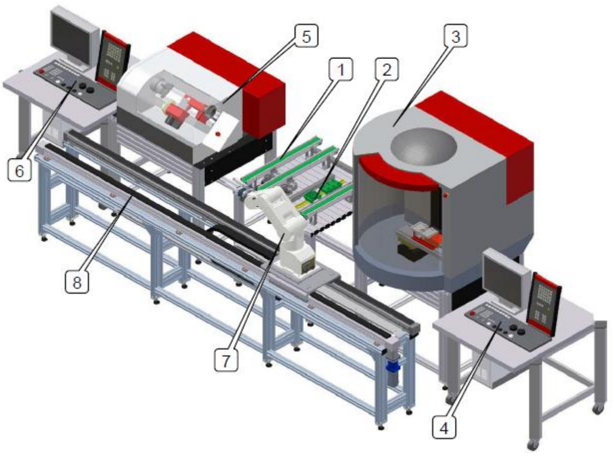
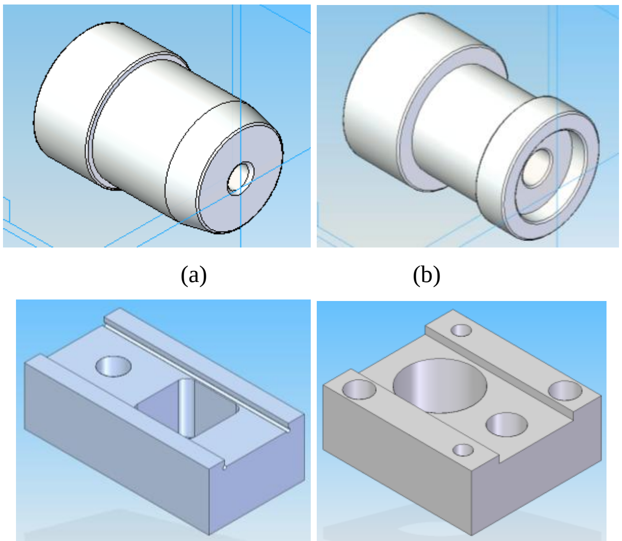


Fig. 1. Flexible manufacturing cell.

The parts to be processed in the cell are shown in Fig 2:

1) two cylinder parts (Fig. 2a and Fig. 2.b), these will be processed on CONCEPT TURN 55 CNC lathe;

2) two prismatic parts (Fig.2.c and Fig.2.d), these will be processed on CNC milling machine CONCEPT MILL 55.



(a) (b) (c) (d)

Fig. 2. The parts that will be processed on the fabrication cell.

Each of the four parts, that will be included in the manufacturing process has a timing, if we consider a referral moment $t_0 = 0$. Therefore: Part 1 (first cylinder part -Fig.2.a) is the part that comes first in the cell; Part 2 (second cylinder part- Fig.2.b) is the fourth part that comes into the cell; part 3 (Fig.2.c) is the second and part 4 (Fig.2.d) is the third part that comes into the cell.

Another important parameter in the evaluation of a manufacturing system is time processing. The processing time of part 1 on CNC lathe is 7 minutes, the processing time of part 2 is 9 minutes, the processing time is 18 minutes for part 3 and part 4 is processed in 21 minutes.

B. Model with coloured Petri nets

1) Colors

The set of colors to describe the two machines is defined "*masina*". This will have two values: M1 for lathe CONCEPT TURN 55 CNC and M2 for milling machine CNC CONCEPT MILL 55 (*colset masina = with M1 | M2*), meaning:

$$\mathbf{masina} = \{\mathbf{M1, M2}\} \quad (1)$$

It also defines the set of colors that will be associated with the parts to be processed in the cell. The colors will be called "*piesa*" and will have the following values: P1 for part 1, part 2 for P2, part 3 for P3, part 4 for P4 (*colset piesa = with P1 | P2 | P3 | P4),* meaning:

$$\mathbf{piesa} = \{\mathbf{P1, P2, P3, P4}\} \quad (2)$$

To the RV-2AJ Mitsubishi robot is associated the color "*robot*" with the value R1 (*colset robot=with R1*).

To highlight the fact that each part is processed on a given machine, it defines the complex color "*program*" as the cartesian product of the pieces and machines:

$$\mathbf{program} = \mathbf{piesa\ x\ masina} \quad (3)$$

This cartesian product will retain only these complex color pairs: {P1, M1}, {P2, M1}, {P3, M2} and {P4, M2}.

2) Variables

In [1] specifies that in the coloured Petri networks to each arc is assigned a function. In the case of CPN Tools to each arc is assigned a variable. The variable "*p*" can have values P1, P2, P3, P4:

$$\mathbf{p} \in \{\mathbf{P1, P2, P3, P4}\} \quad (4)$$

The variable "*m*" may have the values M1 and M2:

$$\mathbf{m} \in \{\mathbf{M1, M2}\} \quad (5)$$

The variable "*r*" can have only one value:

$$\mathbf{r} \in \{\mathbf{r}\} \quad (6)$$

The model construction with coloured Petri nets suppose to define the variable to make the connection between the song and the machine on which it is processed

$$\mathbf{p} \times \mathbf{m} \in \{\mathbf{(P1, M1), (P2, M1), (P3, M2), (P4, M2)}\} \quad (7)$$

3) *Positions*

Position P1 shapes the stock of parts. To this position is associated the complex color "*program*". Initial token of position P1 is made from the complex colors: {P1, M1}, {P2, M1}, {P3, M2} and {P4, M2}

Position P2 shapes that the part is found in robot gripping device. Position P2 is associated with the complex color "*program*". Initial token of position P2 is 0.

Position P3 shapes that the part is on the machine for processing work. Position P3 is associated with the complex color "*program*". Initial token of position P3 is 0.

Position P4 shapes that the part is found in robot gripping device. Position P4 is associated with the complex color "*program*". Initial token of position P4 is 0.

Position P5 shapes that the part that has been processes is finit part storage. Position P5 is associated with the color "*piesa*". Initial token of position P5 is 0.

Position P6 shapes the Mitsubishi RV-2AJ robot. Position P6 is associated with the color "*robot*". Initial token of P6 position is R1, meaning that the robot is available. The absence of the color R1 on the position P6, signify that the robot is busy.

Position P7 shapes the working machines. These positions can be assigned color "*masina*". The initial token of position is composed from M1 and M2 colors. This means that the two machines are available.

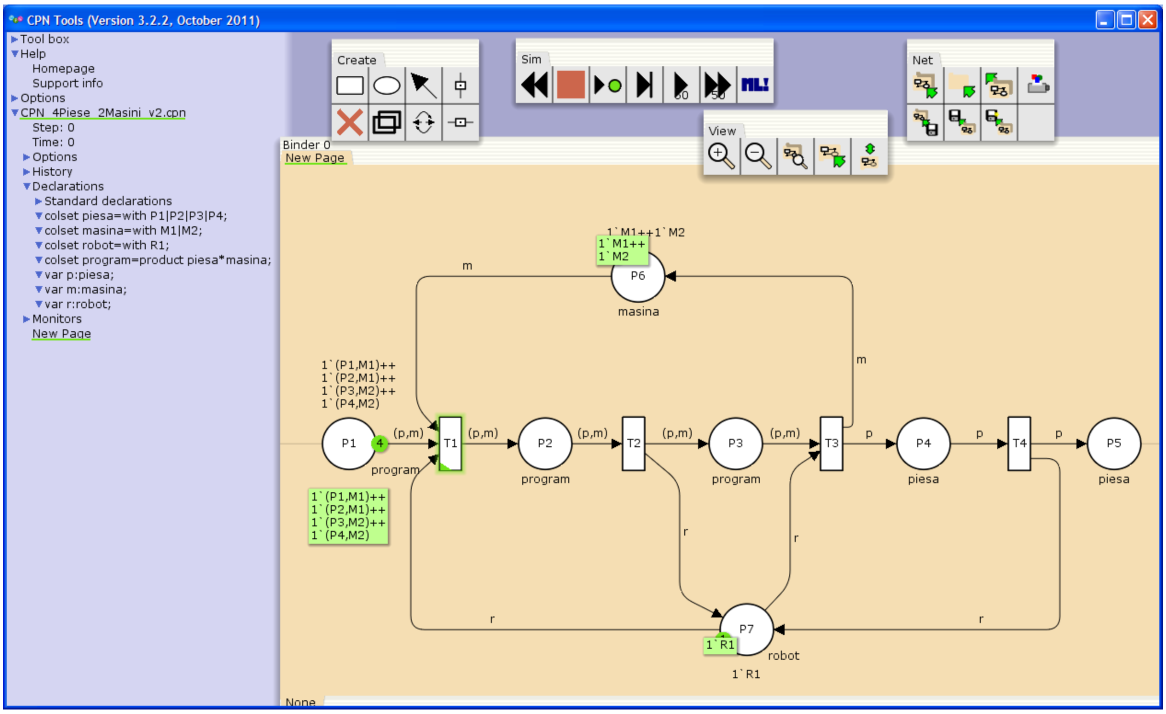


Fig. 3. Coloured Petri nets model

4) *Transitions*

Transition T1 shape the part translation on the robot Mitsubishi RV-2AJ, to be loaded on the machine work.

Transition T2 shape that the part is on the working machine and is processed.

Transition T3 shape that the part was taken from the machine.

Transition T4 shape that the part is in the finite parts storage.

Fig. 3 shows the model build with coloured Petri nets CPN Tools without considering the time factor.

A. *Model with timed coloured Petri nets*

Timing will be developed from three perspectives:

1) Color timing (marks);

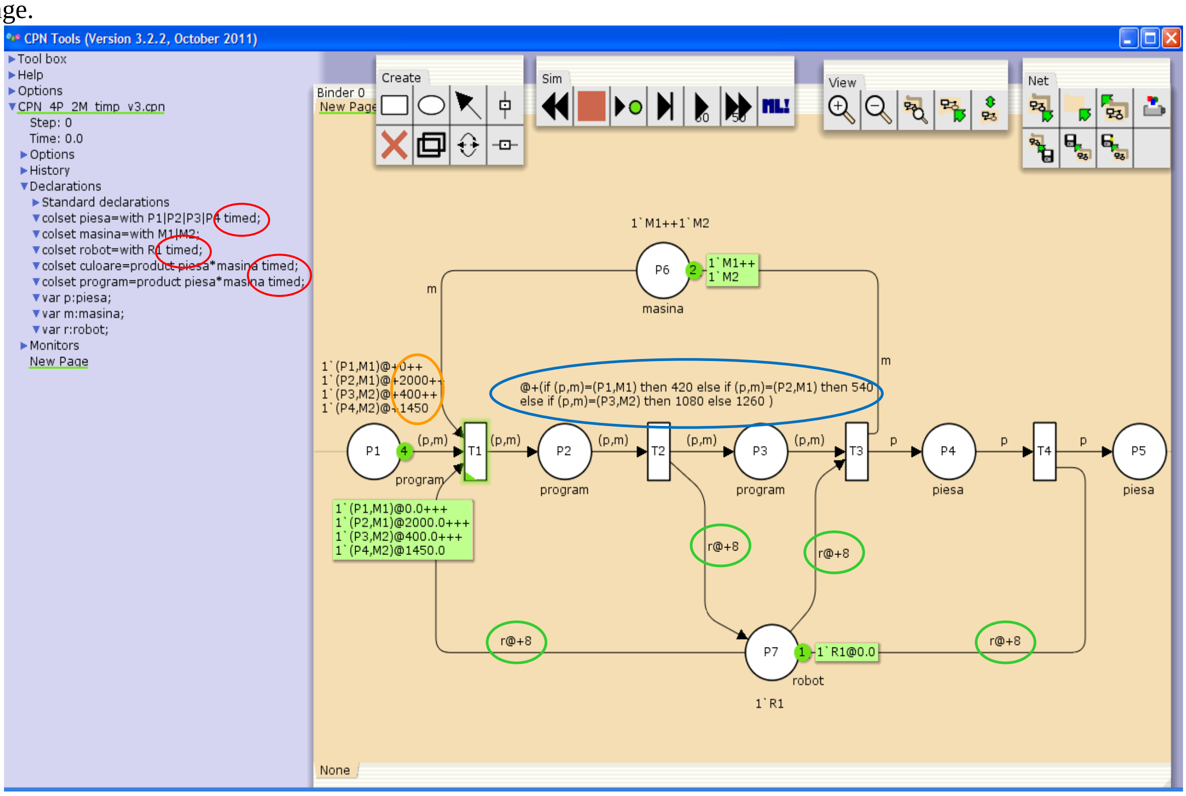


Fig. 4. Timed coloured Petri Nets model

2) Transition timing;
3) Arcs timing.

The simulation time associated to colors are used to highlights the arrival of parts in the system. Thus, we define the simulation time *(P1, M1) @ 0; (P3, M2) @ 400; (P4, M2) @ 1450 and (P2, M1) @ 2000* (Fig. 4).

The timings associated to transitions are used to define the processing time. The transition which shapes the processing of the part is transition T2. To this transition was associated in fact four timings, one for each part. Actual value of the timing at a time, is the result of the instruction *if: @ + (if (p, m) = (P1, M1) then 420 else if (p, m) = (P2, M1) then 540 else if (p, m) = (P3, M2) then 1080 else 1260*. It has been consider the second to be unit measurement.

The timings associated to arcs was define to show the manipulation times corresponding to Mitsubishi RV-2AJ robot. To the variable (function) which load the arcs: P7→T1; T2→P7; P7→T3 si T5→P7 it was associated the simulation time *r @+8*.

B. Simulation

Considering that the information associated to model is built with coloured Petri nets it is simulate the cell processing of the four parts. It can be see the end of processing times of each part: P1, 420 seconds; P2-3300 seconds; P3-1500 seconds; P4-3300 seconds. It also can evaluate the total functioning time of the robot: 3308 seconds (Fig. 5).

Simulation involves the execution of 16 steps; the number of executions transitions is 16.

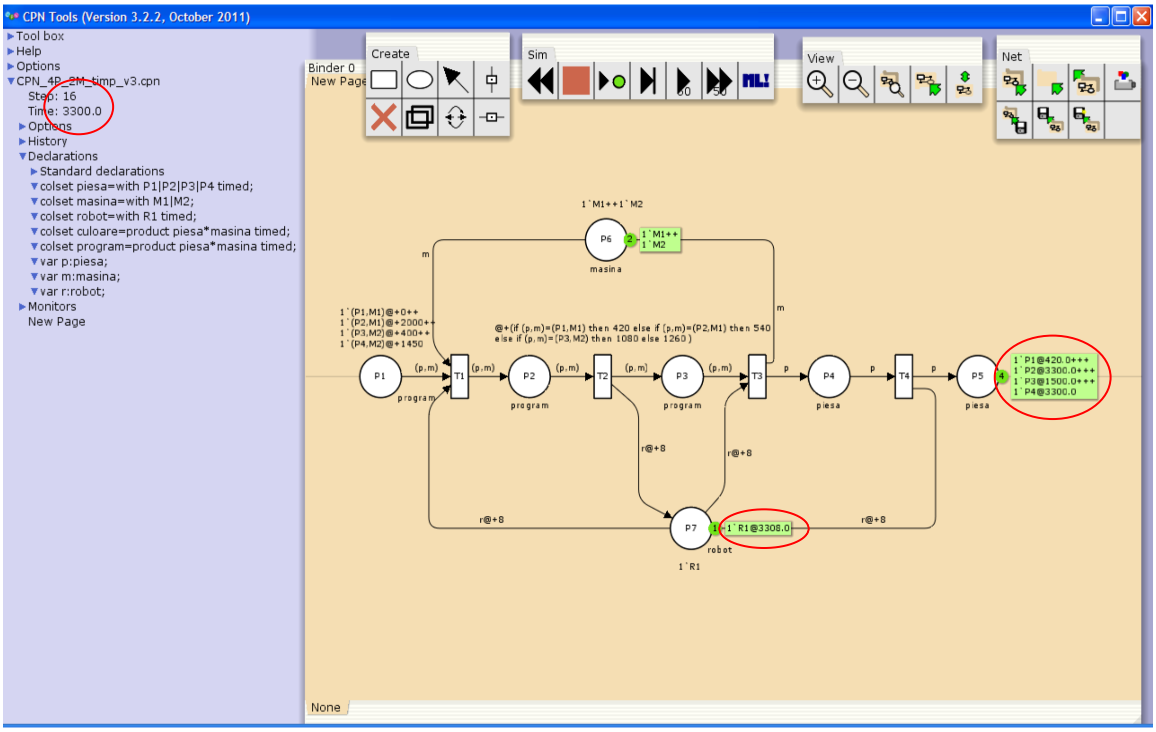


Fig. 5. Timed coloured Petri Net model, after simulation

III. Conclusion

One advantage of using coloured Petri networks is the fact that they allow the replacement of token with symbols type (colors) which significantly simplifies the model. Color token type can be interpreted as a parameter that can take different values. In our case, it can be considered more parts and more machines.

In ordinary Petri nets case, the timing are associated to transitions (T-timed Petri nets) or positions (P-timed Petri nets). In coloured Petri nets case, the timing can be associated to color, transitions and arcs. This allows increasing the description fidelity of the real system through the model.

Future research will follow the way in which models with coloured Petri nets can be used to evaluate the processes with random character (stochastic).

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