A FLOW REGULATION BY GENERALIZED PETRI NET

Marc Bourcerie

University of Angers, LISA-EA 4014-62
62 av N-D du Lac
49000 Angers, France

marc.bourcerie@univ-angers.fr (Marc Bourcerie)

Abstract

We suggest a model representing the regulation of flow on production site, composed of two parallel production lines. After a comparison of flow, the model is able to modify, in real time the coming in flow of each line, in order to counterbalance the loads of production. Then we show that it is possible to carry out a plan of regulation with uncolored Petri nets (PN) using modules (gauge, sequencer) which could be used for others applications.
The regulator takes the informations of flow from the two lines and generates a sequence through the sequencer, depending on these informations. This sequencer orientates two products towards one of these two lines. Our choice will be the using of ordinary Petri nets to obtain these models.
We propose a model of gauge (composed by six elementary cells) able to give, when he is requested, a number of tokens in one of two places Psup0 or Psup1 depending on the difference between the quantities of tokens initially in places "Pf0" and "Pf1".

Some simulations have been carried out to verify the functioning of the model. These simulations have confirmed the theoretical aspect. However, we have tested the good functioning of a reduced model, with a gauge of only two cells. The number of cells decreases the number of dispatched objects before the end of transient behaviour.

Keywords: Petri Net, Complex Sequencing, Flow Regulation.

Presenting Author's biography

Marc Bourcerie obtained the PhD in 1988. His work was about the aging of N-MOS transistor. In 1989, he joined the University of Angers, where he obtained, in 1996 "HDR" degree. In LISA laboratory, he works on the modelling of complex systems by generalized or coloured Petri Nets.

1 Introduction

1.1 Description of problem

Since a few years, we are interested by the modelization of production systems by Petri Nets. It is important to have a tool of modelization, able to analyze, verify, simulate and command a process. One of frequent problem found in the production line domain, is the supervision and control of production flow. In this presentation, we are particularly interested by the modelization of regulation problems. This kind of problems occurs when appears a failure during the process. In the proposed example, two lines work on the same products in parallel. If one of these two lines is slowed down (or accelerated), it is necessary to change the flows on two lines. Unfortunately, there is not a standard solution for this kind of problem. The measurement of flow is not sufficient to take a decision. This measurement must be completed by a measurement of density of objects on the site (a measurement of flow do not make a distinction between a saturated and an empty site). Petri Nets have been frequently used to represent the production systems and to try to solve some optimisation problems [1-7]. The basic model of a production line is extremely simple, seeing that he is make up with a string of places and transitions, from input to output of the line. The complexity of model increases when the constraints of specifications are more and more numerous. One can end at a very complex model.

Our goal is here, introducing gauge and sequencer notions in a first approach, to show that it is possible to make a model of regulation by generalized PN. This presentation proposes a particular solution when it has been decided to decrease the flow of a line where the measured flow is greater.

Now our purpose is to find models able to represent the flow (of tokens) in order to allow diversion. The next paragraph shows the initial principle of this regulation. One can notice that this model can be in interaction with a real process through a modelling tool.

Regulation loop

Deliberately, we begin this work with a PN using to develop our modelization. The initial specification will be very simple, considering two "concurrent" production lines or instead "substitute" lines, in the carrying out of two similar tasks. The global model will be built by steps. The surveillance of flow in one point of each line and the comparison of theses flows must allow an action in upstream of the lines.

The regulator takes the informations of flow from the two lines and generates a sequence, through the sequencer, depending of these informations. This sequencer orientates the products towards one of these two lines. Then, we obtain the schema of figure 1.

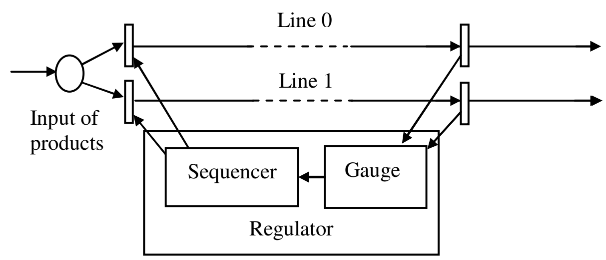

Fig 1 Schema of regulation

1.2. Choice of Generalized or Colored PN

The sequencer is constituted of two parts :

- The Gauge, which must capture the flow in order to drive the sequencer.

- The sequencer which will give the sequence for the regulation.

The purpose is to make a dynamical evolution of the sequence (then the PN in real time).

Several options are possible: Generalized Petri Nets or Coloured Petri Net. The final choice is essentially guided by the qualities of the sequencer. However, we have several solutions to make a dynamical evolution of a Petri Net: modification of links between places and transitions, modification of weight affected to these links, modification of initial marking or modification of functions (coloured Petri Nets). We have to make a choice in order to give the best flexibility for these transformations.

1.3. Some Basical Definitions

A Petri net is a set of places, transitions linked by weighted arcs. Some tokens take up the places and are able to firing transitions, following a number of laws.

A given transition can be fired if and only if one can find in every upstream places of this transition, the number of tokens corresponding to the weight of the arcs respectively linking each of these places to this transition. An example of firing is given in figure 2.

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Fig 2 : Firing of a transition

Every transition which can be fired is immediately fired. The fired transition gives in each downstream place, a number of tokens equal to the weight of the corresponding arc.

Mathematical support: Incidence matrix and invariants :

Each Petri net is described by an incidence matrix where each element w_{ij} is equal to the number of tokens added or subtracted to the place « j » when transition « i » is fired.
Let be a Petri net with « n » places and « m » transitions.

$$\sum_{i=1}^{n} \lambda_i m(P_i) = K$$

P-Invariant is a vector $P^T = (l_1, l_2, \ldots\ldots.l_n)$ with : $P^T W = 0$
Let be m(Pi) the number of tokens in the place Pi. Whatever the evolution of marking, we always have:

T-Invariant is a vector $T = (m_1, m_2, \ldots\ldots.m_m)$ with : $WT = 0$
Where m_i is the number of firing of transition « i » during the sequence « T ». At the end of sequence « T », The PN comes back to his initial marking

The invariant theory is very useful for the building and to verify models.

2. Introduction of specifications

Previously [8], we have shown that it was always feasible to model a complex sequencer by Petri net. We have developed a method to built these models. Then, for example, one can distribute resources between « n » consumers, depending on a periodical sequence, as complex it may be. The problem of the evolution of the model need a modification in real time of the structure by the modification of the links of Petri net [9]. The solution of coloured Petri nets (Fp) [10] has been proposed. It carries out improvement, involving only a modification of functions allocated to the links. Unfortunately, with this solution, we miss of readability, because we must define a function for each sequence. Then we must manage the commutation of functions. This solution is not used here.

The specifications are often less complex in reality. Then, our study can be focussed on the applications for two lines (then we have a binary sequence). Our choice will be the using of ordinary Petri nets, for a better readability of the solutions. We will restrict the proposed sequences in order to obtain a modification of the model, only by a changing of initial marking.

In a practical point of view, we can limit to sequences of type S = <010101…01>, where the resource is alternatively dispatched on line 0 and line 1. Then we can favour one of these lines, adding some 0 or some 1 at the end of this sequence.

3. Model of dynamical sequencer

The proposed model (figure 3) generates this type of sequence S = <0101….01>.

In this PN, there is not effective conflict, due to the token situated alternatively in the places P0 or P1. then, the transitions Ts0 et Ts1are alternatively fired, directing the resource (place E) to the line 0 and line 1. However, the place C allows to count the number of objects directed to lines 0 and 1. This place is emptied as soon as this number is equal to “n” by the firing of Tn. Thus, one can define a sequence of length “n” between two firing of Tn. One can notice that the sequence is constituted of an equal number of 0 and 1 if n is even.

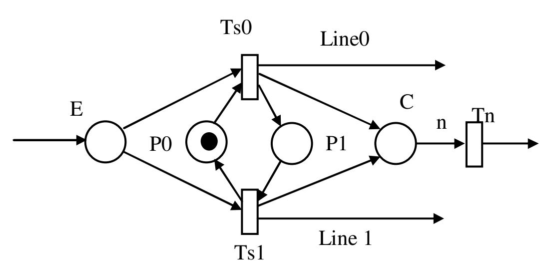

Fig 3. Sequencer <0101….01>

The following model allows to insert a given number of 0 or 1 at the end of the sequence previously defined. If there is “k” tokens in place Psup0 (resp Psup1), the transition T’s0 (resp T’s1), which has priority, add “k” 0 (resp 1) in the sequence.

These added tokens decrease the marking of place C. Then, this adding of tokens delays the firing of Tn and we obtain a sequence of length “n + k” between each firing, with an adjustable “k” value. Like in the last model, this one does not present effective conflict.

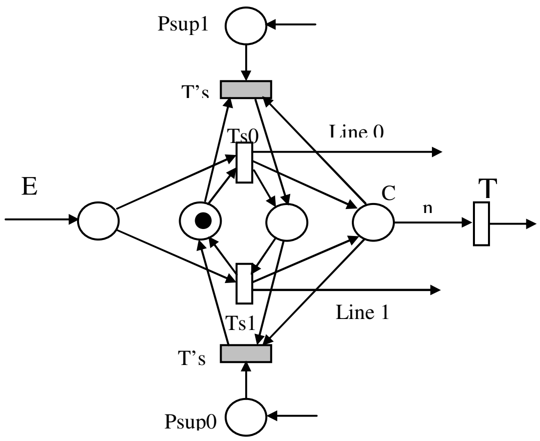

Fig 4. Extended sequencer <0101….01>

4. Model of gauge and measure of flow

4.1 Measurement of flow

The place Pf (figure 5) receives a token for each firing of transition Tf. Then, this place allows the measurement of flow. This model is used on the entries of the gauge (places Pf0 et Pf1 in figure 6). These two places empty of its tokens as soon as the cells of gauge are free.

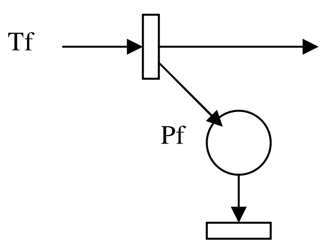

Fig 5. Measurement of flow

4.2. Model of gauge

We propose now (figure 6) the model of gauge, able to give, when he is requested, a number of tokens in one of two places Psup0 or Psup1 depending on the difference between the quantities of tokens initially in places « Pf0 » and « Pf1 ». For example, if there is equal number of tokens in these two places Pf0 and Pf1, there will not have token in the places Psup1 and Psup2.

Here, the gauge is arbitrary composed by 6 cells. If the number of cells is "2k", the initial sequence (of length "n"), can be extended by "k" 0 or "1"

For example, if a token appears in the place Pf0 (it signifies that Tf0 was previously fired), the first (top) transition of gauge is fired. A token appears in C1a and the second transition of gauge is fired...etc. Then, there will be 4 tokens in the column C1a-C6a and 2 tokens in column C1b-C6b.

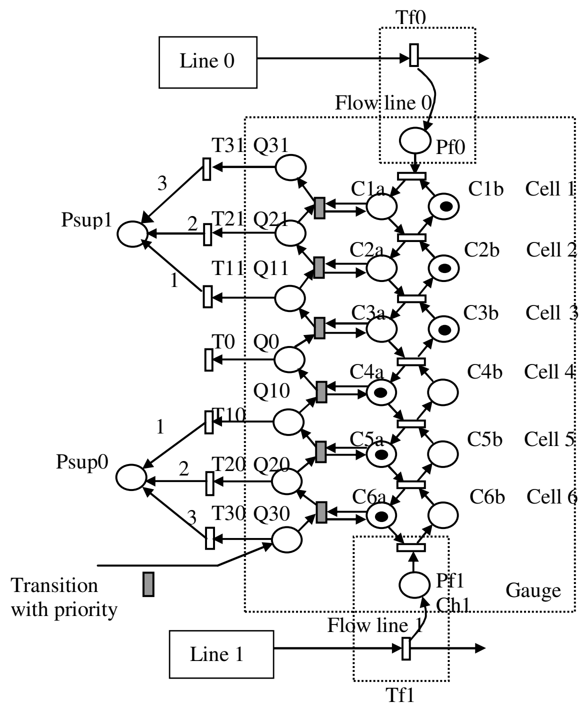

Fig 6. Model of gauge with 6 cells

We define :

Ch0 et Ch1 marking of places Pf0 and Pf1 respectively.

Ch0i et Ch1i initial markings of Pf0 and Pf1 respectively.

Cia et Cib the markings of the two places of cell "i" of the gauge.

Taking stock of P-invariants of the gauge :

$$Ch\,0 + \Sigma Cia - Ch\,1 = Ka \qquad (1)$$

$$- Ch\,0 + \Sigma Cib - Ch\,1 = Kb \qquad (2)$$

$$Cia + Cib = 1 \qquad (3)$$

$$\Rightarrow \qquad \Sigma Cia + \Sigma Cib = 6 \qquad (4)$$

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(1) - (2) $\Rightarrow$

$$2(Ch\ 0 - Ch\ 1) + \Sigma Cia - \Sigma Cib = Ka - Kb$$

(4) $\Rightarrow$

$$2(Ch\ 0 - Ch\ 1) + 2\Sigma Cia - 6 = Ka - Kb \qquad (5)$$

Where Ka and Kb are two constants we will determine. The initial marking gives :

$Ka = Ch\ 0i - Ch\ 1i + 3$ and

$Kb = -Ch\ 0i + Ch\ 1i + 3$

Then : $Ka - Kb = 2\ (Ch\ 0i - Ch\ 1i)$

When all the tokens of the places Pf0 and Pf1 have been consumed :

$$\Sigma Cia = Ch\ 0i - Ch\ 1i + 3 + Ch\ 0\ f - Ch\ 1\ f \qquad (6)$$

with : $Ch\ 0\ f = Ch\ 1\ f = 0$

consequently : $\Sigma Cia = 3 + Ch\ 0i - Ch\ 1i$

After the request of the gauge by creating token in the place Q30, this token goes up in the column of places Q30, Q31, as long as he is not caught by one of the transitions T30 to T31, what occurs when the correspondent place Cia is empty.

Then we obtain the following markings (table 1) in Psup0 and Psup1 after running of token in the column Q30 to Q31. In this table, the number of tokens in each place or each set of place is shown.

Then we have :

If $\Sigma Cia<3$,	$Psup0=3-\Sigma Cia$	$Psup1 = 0$
If $\Sigma Cia=3$,	$Psup0=0$	$Psup1=0$
If $\Sigma Cia>3$	$Psup0=0$	$Psup1=\Sigma Cia - 3$

5. Assembling

We propose now a model able to dispatch the tokens (or the objects) between to lines (figure 7). The used sequence has initially a length of « n » and can be extended by « k » 0 or 1. The dynamical aspect of this dispatching is due to the request from sequencer to the gauge at each end of sequence. It allows the reading of difference of flow between line 0 and line 1. In the place Psup0 or Psup1 will appear a number of tokens corresponding to the numbers of complementary 0 or 1. Then, by this process, the line with the more important flow will be relieved in aid of the other.

Tab 1: Markings of gauge

C6a	C5a	C4a	C3a	C2a	C1a	ΣCia	T fired	Psup0	Psup1
0	0	0	0	0	0	0	T30	3	0
1	0	0	0	0	0	1	T20	2	0
1	1	0	0	0	0	2	T10	1	0
1	1	1	0	0	0	3	T0	0	0
1	1	1	1	0	0	4	T11	0	1
1	1	1	1	1	0	5	T21	0	2
1	1	1	1	1	1	6	T31	0	3

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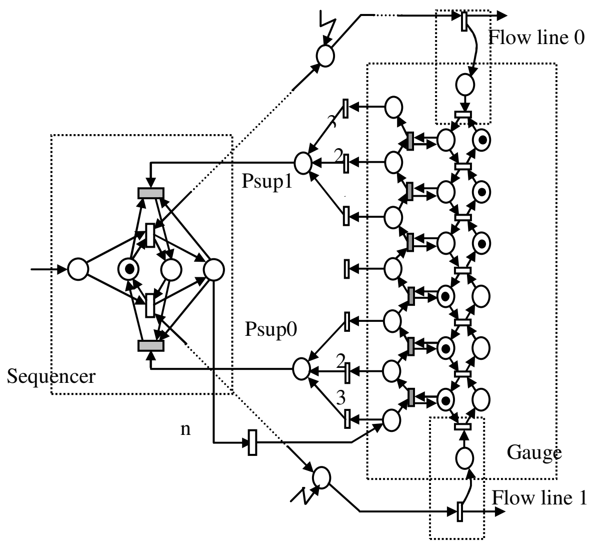

Fig 7. Assembling

6. Conclusion

Our purpose was to show that it is possible to built a regulation of flow with Generalized Petri Nets. This tool is well known for his user friendliness and allows the simulation, the analysis and verification.

We have built this regulation model with two specific units (gauge and dynamical sequencer) which would be used for others applications.

The first one allows the measure a difference of flow, the second one is able to generate as sequence with variable length in order to correct the flow observed on two lines.

Now, we use a tool which was developed in our laboratory (Petri Maker) for modelling and simulation. The results we have obtained are corresponding to the theoretical development. We now try to improve this model in order to increase the possibilities of the model. On the other hand, we try to develop some models in order to take decisions depending of flows and density of objects on sites.

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